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THE CHILIAN NITRATE OF SODA MINES AND WORKS.

THE two nitrate oficinas of Jaz Pampa and Paccha count among the most important, and are undoubtedly the most picturesquely situated, of any on the Pampas of Tarapaca. They are built on opposite sides of a deep quebrada, or, as it would be termed in the mining districts of North America, gulch, through which the Nitrate Railway passes. Indeed, the word Jaz, a local term implying divided, is here used to denote the fashion in which the level surface of the pampa has been rent apart by some bygone convulsion of nature. Advantage has been taken of this natural formation to lay out the oficinas of the Jaz in such wise as to obtain unusual facilities for commodious and economical working. The caliche or raw material of nitrate, having been extracted from the calicheras situate on the Pampas, is brought to the crushers erected at the summit of the maquina, and, being run through them, falls into the boiling tanks below. The nitrate in solution flows into the bateas or precipitating tanks, where on cooling it crystallizes; while the earthy refuse, or ripio, left in the boiling tanks, is cleared out by hand, and shot from tip cars into the valley below. The nitrate ground attached to the two oficinas contains caliche of very high quality; that on the Jaz Pampa side of the quebrada is, indeed, of unusual thickness of stratum and richness in nitrate. The caliche on the other side is also rich, and has the advantage of lying near to the surface. Another advantage is that these oficinas are the two lying nearest to the terminal port of shipment, Pisagua, and hence enjoy cheaper rates of freight on the railway for their products than any others. Up to a recent date they were the joint property of Colonel North and Mr. Charles Comber; but it is intended to bring them out as a joint stock company under the title of the La Paccha Nitrate Company.—*Illustrated London News.*

[Continued from SUPPLEMENT, No. 724, page 11563.]

THE MOLECULAR STRUCTURE OF MATTER.*

GENERAL KALAKOUTSKY proposed, for the purpose of setting up beneficial internal stresses, that tubes which were being annealed should be cooled from the inside by a jet of steam, air, water, or oil; and he advocated the practice of testing the effects of each new method of manufacture or of treatment by the careful measurements of slices of the finished material instead of working at random, as is still very much the practice. It is evident, also, that a sample of steel cut out of a gun hoop or crank shaft, and tested, can afford no indication of the available tenacity of the same sample *in situ*. When released from the constraint of its surroundings, the particles must, of necessity, change their condition, for the disturbing forces have been removed; and the probability is that, if the steel be good, the test will prove satisfactory, especially if some time be allowed to elapse between cutting out the sample and testing it, and a false security will be engendered, such as has often led to disastrous results.

The influence of time on steel seems to be well established; the highest qualities of tool steel are kept in stock for a considerable period; and it seems certain that bayonets, swords, and guns are liable to changes which may account for some of the unsatisfactory results which have manifested themselves at tests repeated after a considerable interval of time. As all these things have been hardened and tempered, there must necessarily have been considerable constraint put upon the freedom of motion of the particles. This constraint has gradually been overcome, but at the expense of the particular quality of the steel which it was originally intended to secure.

I have now laid before you the views respecting the constitution of matter which I think are gaining ground, which explain many phenomena with which we are familiar, and which will serve as guides in our treatment of metals, and especially of alloys; but I must admit that the subject is still by no means clear, that a great deal more definition is wanted, and that we are still awaiting the advent of the man who shall do for molecular physics what Newton did for astronomy in explaining the structure of the universe.

PETROLEUM.

One of the most remarkable features of the last thirty years is the introduction of petroleum and the wonderful development to which the trade in it has attained.

Under the generic name of petroleum are embraced a vast variety of combinations of carbon and hydrogen, each of which is distinguished by some special property. At ordinary temperatures and pressures some are gaseous, some are liquid, and some solid, and most are capable of being modified by suitable treatment under various temperatures and pressures. The employment of petroleum in the arts is still extending rapidly. Used originally for illuminating purposes, it is now employed as fuel for heating furnaces and steam boilers; as a working agent in heat engines; valuable medicinal properties have been discovered; and as a lubricant it stands unrivaled. As an illuminant, even in this country, it is, to a large extent, superseding every other in private houses, and even in public lamps, because it gives a cheaper and more brilliant light than ordinary gas, and leaves the consumer free from the tyranny of great and privileged companies. As fuel it is especially convenient, cleanly, and economical. Stored in tanks of suitable construction, it is sprayed into the furnace without labor and without creating dust and dirt; and it is especially convenient in locomotive and marine work on account of the rapidity, ease, and cleanliness with which it

* Presidential address to the Mechanical Science Section of the British Association, Newcastle, 1889. By William Anderson, M. Inst. C.E.

THE NITRATE OF SODA MINES AND WORKS IN CHILI.

can be run into the tender or into the oil bunkers of a ship.

PETROLEUM AS A MOTOR.

As a working agent in heat engines it is employed in two ways. First as a vapor, generated from the liquid petroleum contained in a boiler, very much in the same way as the vapor of water is used in an engine with surface condenser, the fuel for producing the vapor being also petroleum. Very signal success has been obtained by Mr. Yarrow and others in this mode of using mineral oil, especially for marine purposes and for engines of small power; there seems to be no doubt that by using a highly volatile spirit in the boiler, a given amount of fuel will produce double the power obtainable by other means, and at the same time the machinery will be lighter and will occupy less space than if steam were the agent used.

The other method is to inject a very fine spray of hot oil, associated with the proper quantity of air, into the cylinder of an ordinary gas engine, and ignite it there by means of an electric spark or other suitable means. Attempts to use oil in this way date back many years, but it was not until 1888 that Messrs. Priestman Brothers exhibited at the Nottingham Show of the Royal Agricultural Society an engine which worked successfully with oil, the flashing point of which was higher than 75° Fahr., and was therefore within the category of safe oils. The engine exhibited was very like an ordinary Otto gas engine, and worked in exactly the same cycle. A pump at the side of the engine forced air into a small receiver at a few pounds pressure to the square inch. The compressed air, acting by means of a small injector, carried with it the oil in the form of fine spray, which issued into a jacketed chamber heated by the exhaust, in which the oil was vaporized.

The mingled air and oil was thus raised to a temperature of about 300°, and was then drawn, with more air, into the cylinder, where, after being compressed by the return stroke of the piston, it was exploded by an electric spark, and at the end of the cycle the products of combustion were discharged into the air after encircling the spray chamber and parting with most of their heat to the injected oil. The results of careful experiments made by Sir William Thomson and by myself on different occasions were that 1·73 lb. of petroleum were consumed per brake horse power per hour; but the combustion was by no means perfect, for a sheet of paper held over the exhaust pipe was soon thickly spattered with spots of oil. At the Windsor Show of the Royal Agricultural Society this year, Messrs. Priestman again exhibited improved forms of their engine; the consumption of oil fell to 1·25 lb. per brake horse power per hour, and a sheet of paper held over the exhaust remained perfectly clean. They also showed a portable engine of very compact construction, and quite adapted to agricultural use; the ordinary water cart, which has, in any case, to attend a portable steam engine, being adapted to supply the water necessary to keep the working cylinder of the engine cool.

It is hardly necessary to state that the use of petroleum for furnace purposes of all kinds is increasing very rapidly, and the demand has naturally reacted on the supply in promoting improved means of transport; and Newcastle, again, has led the van in this matter, for Sir William Armstrong, Mitchell & Co. have sent out a fleet of steamers constructed to carry the oil in bulk with perfect safety, both as regards the stowage of a cargo so eminently shifting and with respect to risk from fire and from explosion. The enormous consumption of petroleum and of natural gases frequently raises the question as to the probability of the proximate exhaustion of the supply; and, without doubt, many fear to adopt the use of oil, from a feeling that if such use once becomes general, the demand will exceed the production, the price will rise indefinitely, and old methods of illumination, and old forms of fuel, will have to be reverted to.

THE ORIGIN OF PETROLEUM.

From this point of view it is most interesting to inquire, What are the probabilities of a continuous supply? and such an investigation leads at once to the question, What is the origin of petroleum? In the year 1877 Professor Mendeleeff undertook to answer this question; and as his theory appears to be very little known, and has never been fully set forth in the English language, I trust you will forgive me for laying a matter so interesting before you. Dr. Mendeleeff commences his essay by the statement that most persons assume, without any special reason—excepting, perhaps, its chemical composition—that naphtha, like coal, has a vegetable origin. He combats this hypothesis, and points out in the first place that naphtha must have been formed in the depths of the earth. It could not have been produced on the surface, because it would have evaporated; nor over a sea bottom, because it would have floated up and been dissipated by the same means. In the next place he shows that naphtha must have been formed beneath the very site on which it is found—that it cannot have come from a distance, like so many other geological deposits, and for the reasons given above, namely, that it could not be water-borne, and could not have flowed along the surface, while in the superficial sands in which it is generally found no one has ever discovered the presence of organic matter in sufficiently large masses to have served as a source for the enormous quantity of oil and gas yielded in some districts; and hence it is most probable that it has risen from much greater depths under the influence of its own gaseous pressure, or floated up upon the surface of water, with which it is so frequently associated.

The oil-bearing strata in Europe belong chiefly to the Tertiary or later geological epochs; so that it is conceivable that in these strata, or in those immediately below them, carboniferous deposits may exist and may be the sources of the oil; but in America and in Canada the oil-bearing sands are found in the Devonian and Silurian formations, which are either destitute of organic remains or contain them in insignificant quantities. Yet if the immense masses of hydrocarbons have been produced by chemical changes in carboniferous beds, equally large masses of solid carboniferous remains must still exist; but of this there is absolutely no evidence, while some cases occur in Pennsylvania where oil is obtained from the Devonian rocks underlying compact clay beds, on which rest coal-bearing strata. Had the oil been derived from the coal, it certainly would not have made its way downward; much less would it have penetrated an impermeable stratum of clay. The conclusion arrived at is that it is impossible to ascribe the formation of naphtha to chemical changes produced by heat and pressure in ancient organic remains. One of the first indices to the solution of the question lies in the situation of the oil-bearing regions. They always occur in the neighborhood of, and run parallel to, mountain ranges—as, for example, in Pennsylvania, along the Alleghanies; in Russia, along the Caucasus. The crests of the ranges, formed originally of horizontal strata which had been forced up by internal pressure, must have been cracked and dislocated, the fissures widening outward, while similar cracks must have been formed at the bases of the ranges; but the fissures would widen downward, and would form chambers and cavities into which naphtha, formed in the depths to which the fissures descended, would rise and manifest itself, especially in localities where the surface had been sufficiently lowered by denudation or otherwise. It is in the lowest depths of these fissures that we must seek the laboratories in which the oil is formed; and once produced, it must inevitably rise to the surface, whether forced up by its own pent-up gases or vapor or floated up by associated water. In some instances the oil penetrating or soaking through the surface layers loses its more volatile constituents by evaporation, and in consequence, deposits of pitch, of carboniferous shales, and asphalt take place; in other cases, the oil, impregnating sands at a lower level, is often found under great pressure, and associated with forms of itself in a permanently gaseous state. This oil may be distributed widely according to the nature of the formation or the disturbances to which they have been subjected; but the presence of petroleum is not any way connected with the geological age of the oil-bearing strata. It is simply the result of physical condition and of surface structure.

THE INTERIOR SUBSTANCES OF THE EARTH.

According to the views of Laplace, the planetary system has been formed from incandescent matter torn from the solar equatorial regions. In the first instance this matter formed a ring analogous to those which we now see surrounding Saturn, and consisted of all kinds of substances at a high temperature, and from this mass a sphere of vapors, of larger diameter than the earth now has, was gradually separated. The various vapors and gases which diffused through each other formed at first an atmosphere round an imaginary center, gradually assumed the form of a liquid globe, and exerted pressures incomparably higher than those which we experience now at the base of our present atmosphere.

According to Dalton's laws, gases, when diffused through each other, behave as if they were separate; hence the lighter gases would preponderate in the outer regions of the vaporous globe, while the heavier ones would accumulate to a larger extent at the central portion, and at the same time the gases circulating from the center to the circumference would expand, perform work, would cool in consequence, and at some period would assume the liquid or even the solid state, just as we find the vapor of water diffused through our present atmosphere does now. That which is true of changes of physical condition, Henri St. Claire Deville, in his brilliant theory of dissociation, has shown to be equally true with respect to chemical changes; and the cooling of the vapors forming the earth while in its gaseous condition was necessarily accompanied by chemical combinations, which took place chiefly on the outer surface, where oxides of the metals were formed: and as these are generally less volatile than the metals themselves, they were precipitated on to what there then was of liquid or solid of the earth, in the form of metallic rain or snow, and were again probably decomposed, in part at least, to their vaporous condition. The necessary consequence of this action is that the inner regions of the earth must consist of substances the vapors of which have high specific densities and high molecular weights—that is to say, composed of elements having high atomic weights—and that the heavier elementary substances would collect nearer the center, while the lighter ones would be found nearer the surface.

Our knowledge of the earth's crust extends but to an insignificant distance; yet, as far as we do know it, we find that the arrangement above indicated prevails. Hydrogen, carbon, nitrogen, oxygen, sodium, magnesium, aluminum, silicon, phosphorus, sulphur, chlorine, potassium, calcium, substances whose atomic weights range from 1 to 40, became condensed, entered into every conceivable combination with each other, and produced substances the specific gravity of which averages about 2½, never exceeds 4, and are found near the immediate surface of the globe. But the mean specific gravity of the earth as determined by Maskelyne, Cavendish, and others certainly exceeds 5, and consequently the inner portion of our globe must be composed of substances heavier than those existing on the surface, and such substances are only to be found among the elements with high atomic weights.

The question arises, What elements of this character are we likely to find in the depths of the earth? In the first place, since gases diffuse through each other, a certain proportion of the elements of high atomic weight will also be found on the surface of the earth.

Secondly, the elements forming the bulk of the earth must be found in the atmosphere of the sun—if, indeed, the earth once formed part of its atmosphere; and of all the elements, iron, with a specific gravity exceeding 7, and with an atomic weight of 56, corresponds best with these requirements, for it is found in abundance on the surface of the earth; and the spectroscope has revealed the very marked presence of iron in the sun, where it must be partly in the fluid and partly in the gaseous state; and consequently iron in large masses must exist in the earth; so that the mean specific gravity of our planet may well be 5, the value which has been determined by independent means.

It is not easy, however, to define in what condition the mass of iron which must exist in the heart of the earth is likely to be.

Iron is capable of forming a vast number of combinations, depending upon the relative proportion of the various elements present. Thus, in the blast furnace, oxygen, carbon, nitrogen, calcium, silicon, and iron are associated, and produce, under the action of heat, besides various gases, a carburet of iron and slag, the latter containing chiefly silicon, calcium, and oxygen—that is to say, substances similar to those which form the bulk of the surface of the earth.

But these same elements, if there be an excess of oxygen, will not yield any carburet of iron, and the same result will follow if there be a deficiency of silicon and calcium, because of the large proportion of oxygen which they appropriate.

In the same way, during the cooling of the earth, if oxygen, carbon, and iron were associated, and if the carbon were in excess of the oxygen, the greater part of the carbon would escape in the gaseous state, while the remaining part would unite with the iron. It is certain that, in the heart of the earth, there must have been a deficiency of oxygen, because of its low specific gravity; and the argument is supported by the fact that free oxygen and its compounds with the lighter elements abound on the surface.

Further, it must be presumed that much of the iron existing at great depths must be covered over and protected from oxygen by a coating of slag, so that, taking all these considerations into account, it is reasonable to conclude that deep down in the earth there exist large masses of iron in part at least in the metallic state or combined with carbon.

The above views receive considerable confirmation from the composition of meteoric matter, for it also forms a portion of the solar system, and originated, like the earth, from out of the solar atmosphere.

Meteorites are most probably fragments of planets, and a large proportion of them include iron in their composition, often as carbides, in the same form as ordinary cast iron—that is to say, a part of the carbon is free and part is in chemical union with the iron.

It has been shown, besides, that all basalts contain iron, and basalts are nothing more than lavas forced by volcanic eruptions from the heart of the earth to its surface. The same causes may have led to the existence of combinations of carbon with other metals.

FORMATION OF PETROLEUM.

The process of the formation of petroleum seems to be the following: It is generally admitted that the crust of the earth is very thin in comparison with the diameter of the latter, and that this crust incloses soft or fluid substances, among which the carbides of iron and of other metals find a place. When, in consequence of cooling or some other cause, a fissure takes place through which a mountain range is protruded, the crust of the earth is bent, and at the foot of the hills fissures are formed; or, at any rate, the continuity of the rocky layers is disturbed, and they are rendered more or less porous, so that the surface waters are able to make their way deep into the bowels of the earth, and to reach occasionally the heated deposits of metallic carbides, which may exist either in a separated condition or blended with other matter. Under such circumstances it is easy to see what must take place.

Iron, or whatever other metal may be present, forms an oxide with the oxygen of the water; hydrogen is either set free or combined with the carbon which was associated with the metal, and becomes a volatile substance—that is, naphtha.

The water which had penetrated down to the incandescent mass was changed into steam, a portion of which found its way through the porous substances with which the fissures were filled, and carried with it the vapors of the newly formed hydrocarbons, and this mixture of vapors was condensed wholly or in part as soon as it reached the cooler strata.

The chemical composition of the hydrocarbons produced will depend upon the conditions of temperature and pressure under which they are formed.

It is obvious that these may vary between very wide limits, and hence it is that mineral oils, mineral pitch, ozokerit, and similar products differ so greatly from each other in the relative proportions of hydrogen and carbon. I may mention that artificial petroleum has been frequently prepared by a process analogous to that described above.

Such is the theory of the distinguished philosopher, who has framed it not alone upon his wide chemical knowledge, but also upon the practical experience derived from visiting officially the principal oil-producing districts of Europe and America, from discussing the subject with able men deeply interested in the oil industry, and from collecting all the available literature on the subject.

It is needless to remark that Dr. Mendeleeff's views are not shared by every competent authority; nevertheless, the remarkable permanence of oil wells, the apparently inexhaustible evolution of hydrocarbon gases in certain regions, almost forces one to believe that the hydrocarbon products must be forming as fast as they are consumed, that there is little danger of the demand ever exceeding the supply, and that there is every prospect of oil being found in almost every portion of the surface of the earth, especially in the vicinity of great geological disturbances.

Improved methods of boring wells will enable greater depths to be reached; and it should be remembered that, apart from the cost of sinking a deep well, there is no extra expense in working at great depths, because the oil generally rises to the surface or near it. The extraordinary pressures, amounting to 300 lb. per square inch, which have been measured in some wells seem to me to yield conclusive evidence of the impermeability of the strata from under which the oil has been forced up, and tend to confirm the view that it must have been formed in regions far below any which could have contained organic remains.

STANDARD UNIT OF POWER.

The weights and measures in use in this country are a source of considerable trouble and confusion. Besides the imperial measures, which are complicated enough, a great number of local units are in use, so that unwary strangers are not unfrequently deceived, or at any rate, if they hope to escape from mistakes, have to apply themselves to the study of local customs. In the scientific world, again, the metric system is now almost exclusively used, and the same may be said of engineers and manufacturers who have to do with foreign countries in which French measures are in vogue. The same difficulty surrounds the measurement of the power of motors. The unit of power is, indeed, from the nature of the case, common to the whole world—it is unit of weight multiplied by

unit of height—and with us the foot pound, or 33,000 times the foot pound, is generally accepted; but the difficulty lies in determining how the measure is to be applied. Thus, in the case of a water motor—should the power be calculated by the energy latent in the falling water, or in the actual work given off by the motor? In heat engines we have to deal with many variables. There is the initial pressure of the working agent, the terminal pressure, the length of stroke, the number of revolutions per minute, the indicated power in the cylinder, the effective power given off, and the adequacy of the means of supplying the working agent. In the early days of steam, when pressures were pretty uniform, and speed bore a certain relation to the stroke, the diameter of a cylinder was a tolerably close index to the power of the engine, and such simple rules as "10 circular inches to the horse power," which prevailed among agricultural engineers, were tolerably intelligible.

But in these day, when pressures, speeds, and rates of expansion vary so greatly, the size of the cylinder, or cylinders, is no longer a guide, and I imagine that most manufacturers have ceased to class their engines by their nominal horse power. The problem is pretty simple in the case of pumping engines, for there the nominal power may be taken, as it is in Holland, to be the actual work performed upon the water, and perhaps a similar rule might apply to motors driving dynamos, but for most other purposes no simple law is possible.

In my own practice I have, for many years, been in the habit of classing engines by the indicated horse power per one revolution for every probable initial pressure below the maximum one for which the engines were designed, and for various rates of expansion. To facilitate the calculations, I use curves which give the theoretical horse power (on the supposition that steam expands according to Boyle's law) for 10,000 cubic inches of steam measured at the moment of exhaust, which is the volume of the cylinder in single cylinder engines, and the volume of the last cylinder in compounds. These curves are calculated for initial pressures rising by 25 lb., and, in non-condensing engines, for the extreme range of expansion possible, and to fourteen expansions in condensing engines. The true indicated horse power ranges from 80 per cent. to 85 per cent. of the theoretical, as above stated, the precise percentage depending upon the construction of the engine. As large engines are now almost always compound, the size of the cylinders is no guide to the lay mind; hence in answering inquiries, it is necessary by some means to get at the actual horse power expected and to settle the initial pressure, for on this point there is still much timidity among steam users, so that the engine builder has to adapt himself in this, and other particulars, to the needs or prejudices of his customer. In marine engines, again, the difficulty is still greater, because the only measure of the effective power of the engines is the speed of the ship under given conditions of immersion. But the resistance of ships is a complicated matter, not perfectly ascertained yet, so that the speed attained in any new combination of engines and hull is by no means a certainty; hence some recognized measure of the power of a marine engine, depending only on the measurement of the cylinders and boilers, becomes very desirable.

So strongly has the want of a standard horse power been felt by shipbuilders and marine engine makers, that the council of the Northeast Coast Institution of Engineers and Shipbuilders appointed a committee to investigate the subject, and to devise, if possible, a set of rules which would be generally acceptable. The committee made its report in the spring of 1888. They took as their basis the indicated horse power, under certain normal conditions, and propose to call this the normal indicated horse power (N.I.H.P.)

The normal conditions are, briefly, the following:

1. That the steam, of whatever boiler pressure, is expanded to the same terminal pressure.

2. That the expansion is effected by all engines with the same degree of efficiency

3. That the piston speeds of engines of different lengths of stroke are proportional to the cube root of their respective strokes, and further, that the actual loaded trial-trip value of piston speed may be taken as 144 times the cube root of the stroke in inches ($144 \sqrt[3]{S''}$).

4. That in cases in which the engines and boilers bear to each other such proportions as to prevent condition 1 from being fulfilled without thereby violating condition 3, the coal consumption per indicated horse power will not be affected, but will be constant for the same boiler pressure.

5. That the boilers are constructed in accordance with what will be generally recognized as the average practice of the present day in respect of the allowance of steam room in relation to power, the diameter, area, and pitch of tubes, the relation of grate to heating surface, and the area of uptakes and funnel; that average natural chimney draught is used, or, if forced draught be employed, that it does not exceed the natural draught; that the horse power is proportional to the heating surface (H) and to the cube root of the pressure ($\sqrt[3]{P}$); and, further, that the actual loaded trial-trip horse power may be taken as equal to one-sixteenth of the heating surface multiplied by the cube root of the pressure $\frac{(H \sqrt[3]{P})}{16}$

6. That the efficiency of the engine mechanism is constant, and that the propeller is such as to secure that the engines will utilize the boiler power referred to in condition 5 in the manner prescribed by conditions 3 and 4.

Subject to these conditions the normal indicated horse power is found by multiplying the square of the diameter of the low pressure cylinder in inches by the cube root of the stroke in inches, adding to the product three times the heating surface of the boiler in square feet, multiplying the sum by the cube root of the pressure, and dividing the product by 100.

$$\text{N.I.H.P.} = \frac{(D^2 \sqrt[3]{S} + 3H) \sqrt[3]{P}}{100}$$

It is evident from this formula, and from the conditions, that account is taken of all the variables, and that the boiler is regarded as an integral part of the engine. The report gives several useful formulæ deduced from the above. Whether the expressions given are the most convenient possible for general marine practice or not I am not competent to say, but it seems to me that a step has been taken in the right direction in the attempt which has been made to measure marine engines by some rational standard. The members of the committee were all thoroughly practical as well as scientific men; they determined their constants by reference to a large number of successful cases; and I sincerely hope that the question will be pursued by the marine engine builders on the West Coast, and by the constructors of land engines. As engineer to the Royal Agricultural Society, I have frequently had to define the power of engines entered for competition for the society's prizes, and I have experienced the greatest difficulty in laying down rules for the guidance of intending competitors, being fearful, on the one hand, of restricting originality, and on the other, of admitting engines of greatly varying powers.

I have expressed an opinion that the numerous engineering societies which exist at this day have it in their power to promote the advancement of mechanical science in a notable manner by appointing research committees, or by aiding investigations from their abundant means. The Northeast Coast Institution of Engineers and Shipbuilders has done good service in its endeavors to establish a practical measure of the power of marine engines, while the Institution of Mechanical Engineers has, for the last ten years, been steadily promoting researches of an eminently practical nature. Their expenditure has reached the handsome sum of £1,700, and their proceedings have been enriched with reports on the "Hardening, Tempering, and Annealing of Steel," on the "Form of Riveted Joints," on "Friction of High Velocities," on "Marine Engine Trials," and on the "Value of the Steam Jacket." The names of those who are acting on these committees are a guarantee that the investigations conducted by them will rank among the classical works of the profession, and will abundantly justify the liberal expenditure which has been incurred.

INSTRUMENTS FOR MEASURING RADIANT HEAT.*

By C. V. BOYS, A.R.S.M., F.R.S.

LECTURE I.

AT the time that I was honored by the invitation to give a course of Cantor lectures, I was so much absorbed in my experiments on the development of instruments for measuring radiant heat that I naturally turned to that subject as one which I hoped would be worthy of being discussed in the rooms of the Society of Arts.

However, now that the time has come when I have to put before you an account of the different instruments of this class that have been made, and of the principles upon which they depend, I feel, when I consider what splendid courses of Cantor lectures have been delivered in this room, how utterly unable I am to follow in the steps of those that have gone before me, or to treat my subject in the manner that it deserves.

When an ordinary candle burns, heat is developed, which escapes chiefly in the stream of hot air which rises from the flame. This stream is sufficiently powerful to keep a screw of paper at a height of six feet constantly rotating. If there are many candles or lamps, then the number of separate streams unite in a lake of hot air, which may be found resting under the ceiling of the room.

Heat escaping in this way is said to escape by convection. If a piece of copper wire is placed with one end in the flame it also becomes hot, and some heat escapes along the wire, so that a ball supported by wax falls when the wax is melted, or a piece of phosphorus catches fire, or the fingers holding the wire are burnt. This passage of heat through a material which it warms is called conduction. Finally, if the finger is held a few inches away from the flame, and about level with it, though no hot air is driven in that direction, the finger clearly feels the sensation of heat. Heat is escaping in all directions from the flame without warming the air round about, and without being sensible until it falls upon some obstruction, when its existence becomes known.

This heat escaping by radiation may be felt in any room in which a group of gas burners is alight. All that is necessary is to take a sheet of tin plate and hold it in such a position as to reflect the light—and therefore the heat—on to the face. If the plate is suitably bent by hand, not only will it be filled with light, but the heat which then falls on the face is evident at distances at which we might think some very delicate apparatus would be necessary to detect it. The heat felt under these conditions travels through air without appreciable absorption, just as light does. The air is not warmed in the process; the energy of the radiation passes on unchanged, and only becomes sensible as heat when it meets with some obstruction.

In the case of the sun, no heat can escape by convection, for there is no atmosphere outside it in which currents can be produced. None can escape by conduction, for it does not rest upon anything. All the heat which reaches the earth from the sun, all which leaves the sun at all, is, as far as we know, due to radiation.

The relative amount of heat which escapes from hot bodies by the three processes which have been described—convection, conduction, and radiation—varies very widely, but in general, except among the heavenly bodies, the first two between them are far more important factors in the cooling of a body than radiation. The amount of heat which escapes by radiation is freely radiated into all space, so that if the obstructing body is small, or is any considerable distance away, but a small proportion of the radiation falls upon it, the rest, of course, escaping in all directions.

For these two reasons instruments which are intended to measure radiant heat, as it is commonly called—or radiant energy, which is a better term—must in general be capable of showing quantities of heat which are very small in comparison with that stored or developed in the radiating body.

These instruments differ from thermometers in that, when a thermometer gives a steady reading, temperature is indicated, and there is no heat flowing to or from the thermometer. On the other hand, with instruments for measuring radiant heat, instruments that would be called radiometers if Mr. Crookes had not already given that term a special meaning, the actual temperature of the hot body is but one of the numerous factors which determines the indication of the instrument, and, further, the instrument only gives a steady indication when the rate at which it receives heat from the hot body is equal to the rate at which the part of the instrument heated by the radiation loses heat in consequence of its excess of temperature.

At first the exposed part increases in temperature; as it is warmed it loses heat, generally in all three ways, by conduction, convection, and radiation; this loss becomes faster as the temperature rises, and in time a steady state is arrived at, when the rate at which heat is received is equal to that at which it escapes.

Among instruments for measuring radiant heat I cannot do better than at once refer to the thermometer with a blackened bulb *in vacuo*. This instrument will of course, in time, show the temperature of any inclosure in which it may be placed; it then acts as a thermometer simply, and the vacuum round the bulb merely serves to make the process of acquiring the temperature of the inclosure slower than it would be if the intermediate space were filled with air; or it may be exposed to the sun's rays, in which case, if it did not lose heat at all, it would go on rising in temperature, slowly, possibly, but still without stopping, until it acquired the temperature of the sun, or was destroyed in the process.

In this instrument everything is done that can be done to reduce the loss of heat. Because the bulb is in a vacuum, convection of heat is prevented; because the bulb is only supported by a slender stem of glass, conduction of heat to the outer world is almost inappreciable. However, radiation remains, and it is this that determines the temperature to which the bulb will rise when exposed to any given source of radiation.

Though the rate at which the bulb loses heat at any given temperature would be diminished by silvering it, such a silvered bulb would not become actually hotter, because it would absorb heat more slowly in about the same proportion.

The chief advantage that is obtained by the use of the black surface is quickness, for both the gain and the loss go on at a higher rate than would be the case with any other surface, and, therefore, the final or steady state is more rapidly brought about. This instrument would more truly measure the relative heat of the sun's rays if it were fixed in a place having a constant temperature. When it is simply placed out of doors, it is impossible to say what the temperature of the surrounding bodies—the ground, the walls, the sky—really is; but, on the whole, the rate at which heat leaves the bulb is greater in winter than in summer, for a given temperature of the bulb, and, therefore, the temperature to which it will rise for a given rate of radiation is less in winter than in summer.

I have referred to this instrument at this stage because it illustrates well the difference between a thermometer as commonly used and an instrument for measuring radiant heat. It serves both purposes. It shows the temperature of an inclosure when outside radiation is prevented. By its excess of temperature above that of surrounding bodies it shows at what rate heat is being poured into it from the sun or other radiating body.

All instruments when used to measure radiant heat have in the same way some exposed part or sensitive surface, which is heated to such a temperature that it loses at the same rate that it absorbs heat; but in almost all cases there is this difference—instruments for measuring radiant heat do not, as a rule, give any indication of the actual temperature of the sensitive surface, but only of the excess of the temperature of this over that of the rest of the instrument, and thus these indications are equally valuable, whatever the actual temperature may be.

When heat falls upon a thing and warms it, the rise of temperature produces a variety of physical effects, some of which are made use of to determine the rise of temperature, and therefore the rate at which heat falls upon the surface, while most are not conveniently available for this purpose. In the first place, whether the thing is a solid, or, if hollow, it contains a liquid or a gas, the rise of temperature in almost every case produces an expansion which may be made apparent by mechanical or electrical means. If the thing that is warmed consists of a junction of two metals, an electromotive force is set up, producing a current the strength of which may be made a measure of the increase of temperature.

Or, again, if the thing that is warmed consists simply of a strip of conducting material, its electric resistance is altered—increased generally, but decreased in the case of carbon—by a rise of temperature. Any change in the resistance of one part of a circuit through which a current is sent from an external source will alter the strength of the current, and, if by means of a differential galvanometer or Wheatstone's bridge, the effect of the current is balanced, then a change in the resistance will upset the balance, and this disturbance can be made evident by a galvanometer.

These three effects of heat—expansion, thermo-electromotive force, and change of resistance—are the only ones which are turned to account in instruments for measuring radiant heat.

Let us first consider the few instruments that exist in which some material exposed to the radiant heat is expanded by the rise of temperature, and in which the change of volume gives rise to visible effects.

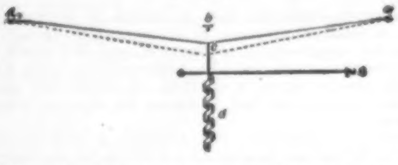
There are many ways of showing, with magnifying levers or other contrivance, that a rod of almost any material is lengthened by heat, but these are so insensitive that they would be quite unable to detect such feeble radiation as is easily measured in other ways. The expansion of a piece of brass wire, or even a glass rod, when slightly warmed, may be shown easily enough by allowing the end to roll over a fine needle,

* Lectures delivered before the Society of Arts, London, 1889. From the *Journal* of the Society.

to which a straw is fastened as an index. Captain Cardew measures the rise of temperature in the wire in his voltmeter by magnifying the expansion with a wheel and pinion. The rise of temperature here, it is true, is not produced by radiation, but is the indirect result of the electromotive force to be measured; but I refer to it, as it is one of the few practically useful instruments in which expansion produced by a rise of temperature in a solid is magnified and made evident by mechanical means.

Professors Ayrton and Perry magnify and measure the elongation due to the rise of temperature in the wire in their voltmeter by a very elegant device (Fig. 1). In the first place, there is a fine wire stretched be-

FIG. 1.



tween two fixed points, *a a*, and pulled on one side by the action of a spring, *d*. When the wire is warmed, the spring pulls it a little further to one side, because it is longer, to a position shown by the dotted line. Now the additional distance to which the wire is pulled to one side is greater than the increase in length of either half of the wire, in the same proportion that *a c* is longer than *b c*; *i. e.*, it would be longer in this proportion if it were not for the fact that, as the angle at *c* diminishes, the power of the spring to stretch the wire diminishes also; nevertheless the lateral motion at *e* is itself considerably greater than the expansion of either half of the wire, and this increased motion is itself enormously magnified by the action of the spring itself. The spring is made with a twisted ribbon of the same shape as the shaving that is produced when a plane, held at an angle, takes a shaving off the edge of a plank. Such a spring (as Professors Ayrton and Perry have shown) twists through a large angle when it is pulled out, even through a small distance; therefore a balanced index on the end of the spring again magnifies the stretch of the wire, and thus a very feeble rise in temperature is made manifest.

I do not think that any one has suggested that these instruments might be used with advantage to measure radiation falling on the wire, nor do I think that any instrument depending on the expansion of a solid could compare in sensibility with those to be described.

The only instrument that I can remember that has been seriously put forward as a delicate means of measuring radiant heat, which does depend on the expansion which a rise in temperature produces in a solid body, is the tasimeter of Edison.

In this instrument the part of the apparatus exposed to radiation is a thin strip of vulcanite or of zinc, which is supported between a screw at one end and a carbon resistance at the other, so that when it expands by heat it shall increase the pressure on the carbon wafer, and so diminish its electrical resistance, an effect which can be easily and accurately observed by well-known electrical methods. There is a good account of this instrument in the *Telegraphic Journal* of November 15, 1878, by Professor Barrett, from which it is possible to get some idea of the sensibility of the tasimeter.

The following paragraph copied from the *Journal* indicates what the instrument will do:

"The heat radiated from one finger held near the cone is more than sufficient to drive the galvanometer index right across, and off the scale. In a letter relating to this tasimeter, Mr. Edison writes to me as follows: 'By holding a lighted cigar several feet away I have thrown the light right off the scale,' and by increasing the delicacy of the galvanometer 'the tasimeter may be made so sensitive that the heat from your body, while standing 8 feet from and in a line with the cone, will throw the light off the scale, and the radiation from a gas jet 100 feet away gives a sensible deflection.'"

Professor Barrett went on to say that he considered the tasimeter to be a more sensitive instrument than the thermopile, as a thermo*scope*, but he did not think it would replace the thermopile, except possibly in investigation of the heat of spectra, owing to the linear form that can be given to the ebonite bar:

I have had no experience with this instrument, and, therefore, what I have to say is only an opinion based on experience of instruments of the highest degree of sensibility and upon our general knowledge or rather ignorance of the behavior of carbon resistances.

There seems to me to be one fatal defect in this instrument as an instrument of precision intended to be used in exact investigations. The indications of the instrument are perfectly arbitrary. We do not know the law according to which the resistance of these carbon wafers changes with change of pressure. Though, as Professor Barrett says, as a thermoscope the instrument may be more sensitive than the ordinary thermopile, which at that time was the most delicate instrument in common use; though when nicely adjusted it might detect a minute change in the radiation falling upon it, the deflection of the galvanometer needle gave no measure of the amount of this change. But if the only fault was that the effect produced was not exactly proportional to the cause, a property common to many most useful instruments, this would be no great objection, for all that would have to be done would be to find out what deflections regulated additions of heat produced—it would be merely necessary to calibrate the instrument. But this I believe is impossible. I do not believe, if the instrument were set up and the calibration curves determined a dozen times, that any two of these curves would be the same. I simply state my belief; if I am wrong, I hope I may be corrected as speedily as possible. It is for this reason that I look upon this instrument simply as a-scope, and not a meter.

Finally, among delicate means of observing the expansion of metal may be mentioned the well known metallic thermometer of Breguet, which consists of three strips of metal—silver, gold, and platinum—soldered together face to face, and wound into a helix. During any change of temperature, the three metals change in length by different amounts, the platinum least and the silver most, and therefore the helix winds up or unwinds. This instrument, like the thermometer, essentially shows actual temperature, and not excess of temperature above surrounding bodies, a feature which does not belong to the voltmeters already mentioned, in which a change of temperature in the whole instrument produces no effect, for all the parts are made to expand alike.

The expansion of a solid might be practically employed in an instrument for measuring radiant heat solely because the solid can be rolled or drawn into very thin strips or wires, which quickly take up the final temperature. The expansion of liquids in tubes cannot conveniently be employed for this purpose, because the amount of liquid that would be sufficient to produce a visible effect would be so great that the time occupied in coming to the final temperature would be enormous. It is only in such cases as that already referred to, where a thermometer *in vacuo* is used to measure the sun's radiation, the changes in which are comparatively slow, that a liquid can be used with any advantage to measure radiant heat.

If the capacity for heat of the bulb of the thermometer is known, and the rate at which it rises in temperature when exposed to the sun's rays, and the average falling in temperature when the sun's rays are screened from the instrument, then, knowing the area exposed by the bulb, we have at once the means of determining absolutely the rate at which heat is reaching the surface of the earth. This measurement is, however, more accurately made by a class of instruments devised for the purpose, of which one of the best known is the pyrheliometer of Pouillet. This consists of a thin box of metal with a flat base; the box is filled with water, and there is immersed in the water the bulb of a delicate thermometer, the stem of which passes down the tube of the instrument. At the lower end of this tube is fixed a disk the same size as the base of the box, so that the observer can, by casting the shadow of the box on this disk, place the bottom of the box square to the rays from the sun. As before, if the capacity for heat of the box, and the rate of heating in the sun, and the average rate of cooling when shaded are determined, we have at once a measure of the rate at which we receive heat from the sun.

Improvements in these instruments have been made by placing the bulb of a thermometer in a cavity maintained at a constant temperature, so that the rate of cooling may be more regular; but as my object in these lectures is to deal rather with instruments of a far more delicate order, I shall not say more on this part of the subject. But perhaps it may be worth while to give the figures that have been obtained for the sun's radiation. The quantity of heat which reaches the earth yearly would be sufficient to melt a layer of ice about 100 feet thick spread over the surface of the earth, and the quantity leaving the sun by radiation is sufficient to melt every hour about 2,000 feet of ice over the whole surface of the sun.

When we make use of the expansion of a gas, we at once have the means of observing far feebler effects than are possible with liquids and solids; in fact, it is impossible to produce an instrument in which the expansion of a gas indirectly shows the presence of radiation which rivals any of the modern thermo-electric apparatus in delicacy, though not perhaps in ease of application.

The first advantages gained by the use of gas is the small weight and the great rate of expansion with rise of temperature. Air expands far more than alcohol; at ordinary temperatures it has a specific heat far less than that of alcohol, and its density is $\frac{1}{700}$ of the density of alcohol. Thus a given quantity of heat applied to a certain volume of air would produce an expansion for each of these reasons greater than it would do if applied to the same volume of alcohol; but as the capacity for heat of the containing bulb, in the case of air, is everything, while in the case of alcohol it is practically nothing, the differences are not quite so great as would at first appear. Still, in spite of the weight of the thin glass bulb, the rate at which the bulb of air is heated is enormous compared with that at which the same bulb of alcohol would be heated, and so it comes to its final temperature far more quickly than would any liquid, and then when it has done so, the expansion is far greater. The expansion of air at constant pressure is most easily found by using a special scale of temperature obtained by adding the figure 273 to the temperature as measured by a centigrade thermometer, and calling this the absolute temperature, then the volume is proportioned to the absolute temperature, if the pressure is constant, or the pressure is proportional to the absolute temperature if the volume is constant. Thus if we make an air thermometer with a bulb two inches in diameter, and a tube one-tenth of an inch in diameter in the bore, the bulb has a capacity of 533 inches of the tube, and therefore the degrees will be very nearly two inches long. The air thermometer, consisting simply of a bulb and an open stem containing an index of some liquid, is a very inconvenient instrument, because every change in the pressure as shown by a barometer will produce its own effect; thus, if in the case taken the barometer were to fall one inch, from 30 to 29, the index would move more than 18 inches from this cause alone. For this reason, and also because in measuring radiant heat we want to observe the increase in temperature, and not the actual temperature, Leslie's differential air thermometer is more suitable. This simple instrument consists of a tube bent into the shape of a U with a bulb at each end, and with liquid filling half the tube. This instrument is rather less sensitive than the simple air thermometer, because in working it sets up a pressure due to the difference of level of the liquid in the two limbs which tends to compress the air where it is expanded, and to make it expand where it is contracted; further, the bulb not exposed to the radiation has the air in it compressed by the expansion of the air in the warmer bulb. The first of these opposing causes is removed in Rumford's differential thermometer, in which the horizontal limb of the U is very long, and the vertical legs short. The short index of liquid in moving along the horizontal tube does not set up any opposing hydrostatic pressure. With the first of these instruments Leslie made his researches on radiant heat before the thermopile had been invented, and, as is so often the case with the true experimentalist, he thus made his most famous discoveries with the simplest possible means.

A modification of the differential thermometer has been devised by Prof. H. F. Weber, of Zurich, of which a very short account is given in the *Archives de Geneve*, 1887, p. 347; so short, in fact, that it is impossible to criticise the instrument until more details have been published.

In this instrument, which Professor Weber calls a microradiometer, the two bulbs of a differential thermometer are replaced by two thin boxes of brass, one end of each of which is made of a plate of rock salt. These boxes are joined to the two ends of a glass tube with a bore about 1 square mm. in area, which has a small bulb blown near each end. The middle of this tube is filled with mercury, and the bulb and about 5 mm. of the tube at each end is filled with a solution of sulphate of zinc, which is prevented by capillarity from escaping into the boxes. If one box is warmed more than the other, then, as in the ordinary differential thermometer, the liquid in the tube is driven a small way toward the other bulb. The peculiarity of the instrument depends on the way in which this motion is made evident. The 5 mm. or so of sulphate of zinc solution between the bulbs, and the mercury in the tube at each end, form two of the arms of a Wheatstone's bridge; the other two arms consist of a pair of resistances as usual, which are put into electrical connection with the sulphate of zinc solution by wires sealed into the bulb. When, owing to the warmth of one of the boxes, the column of sulphate of zinc is lengthened in one end of the tube and is shortened in the other end, the resistance of the one end is increased and that of the other diminished, and thus there is a double disturbance of the balance of the bridge, which at once makes itself felt in the galvanometer.

With this complex apparatus Professor Weber says he can detect a one hundred-millionth of a degree, and that the heat of the moon produces an oscillation of about a hundred divisions of the scale.

I can only conclude, from the very short account at present published, that this instrument is very sensitive, far more sensitive than any one would expect; but whether the indications given by the instrument bear any direct relation to the increase of temperature of the boxes, there is at present no evidence to show. The inventor gives as the theory of the instrument that it is a simple Wheatstone bridge, and that the change of resistance of the arms is the cause of the want of balance. I am inclined to think that this must be very much involved with another action that must certainly come into play. When one of the boxes is warmed, the liquid is driven from that side, but if the increase of temperature—and therefore the acting pressure—is very small, the liquid will not simply move along and take a new position; the ends of the column of mercury will certainly move irregularly, and will also change in shape to a slight extent. Owing to the change of shape, electro-capillary action will be set up—that is, an electromotive force will be set up independently of that due to the battery, which will affect the galvanometer if the bridge connections are so made that the galvanometer is connected with the two bulbs; whereas it should produce no effect—or but a slight effect—on the deflection if the galvanometer connects the mercury thread and the two resistances. Which arrangement is made, the paper does not show. It is very difficult to believe that each hundred-millionth of a degree by which one box is warmed will produce the proper motion of the liquid due to it. The pressure that this temperature represents is about one thirty-thousand-millionth of an atmosphere; that is a pressure of one thousand-millionth of an inch of mercury, or a pressure of about one hundred-millionth of an inch of water. The experience of most physicists is that in a capillary tube with four separate capillary surfaces, such a pressure would not cause any real movement of the liquid as a whole. It is easy to understand that in the case of larger differences of temperature the effect produced will be so enormous that, if all went in proportion, the one hundred-millionth of a degree could be detected; just as in the ordinary wheel barometer—in which the motion of the mercury is greatly magnified—the index would be capable of showing, if all went in proportion, thousandths or perhaps ten-thousandths of an inch, whereas every one knows that in this case you can, by judicious tapping, make the index rest in a variety of positions. I do not wish to be understood to say that this is the case with Weber's instrument, but only that this is what any one would expect. It is to be hoped, therefore, that we shall have details before long which will set these doubts at rest.

The air thermometers referred to so far may be classed among statical instruments. They come to rest when a certain definite change of temperature has been produced, and the position of the index is a measure of that change or difference of temperature.

There is another way in which the expansion of a gas may serve to indicate change of temperature. When a gas—air, for instance—is warmed, and therefore caused to occupy a larger space, the density of the gas of course becomes less. The gas, being lighter, rises, and produces the well known rising current of hot air to which I drew your attention at the beginning of this lecture. These air currents are only too well known to the experimentalist. If, in weighing anything—a crucible, say—the thing being weighed is not quite cold, it warms the air around it, and sets up a current of air which altogether disturbs the balance, and makes the thing seem too light. If the sun shines upon one end of the balance case it warms it, and sets up air currents which again disturb the equilibrium. A gas burner near the balance will do the same thing. Cavendish found, in that famous experiment by means of which he found the mass of the earth, *i. e.*, the number of tons of material which go to make the earth, that a difference of temperature produced by definite means, but still probably too small to be shown with a thermometer, produced disturbances which altogether masked the effect which he was measuring, and these disturbances were simply caused by air currents. The Rev. A. Bennet, F.R.S., in a paper of very great interest, and which is very refreshing in these days of centimeters, grammes, and seconds ("R. Soc. Trans.," 1792), shows how air currents set up in this way may be used to detect the most extraordinarily feeble radiation. I give his own account of his fifth experiment:

"Several other light substances were suspended by fine spider threads and placed in a cylindrical glass about two inches in diameter, as the thinnest part of the wing of a dragon fly, thistle down, and the down of dandelion; of these, the last appeared most sensi-

ble to the influence of heat, for when the down was fastened to one end of a fine gold wire, it would turn toward any person who approached at the distance of three feet, and would move so rapidly toward wires only heated by my hand as very much to resemble magnetic attraction."

Again, Mr. Crookes in some of his researches, when great accuracy was required, was obliged to place his balance in a vacuum, and then, curiously enough, other irregularities were observed which led him to examine in greater detail what happened when radiation fell on light suspended bodies. He found, as had been found before, that these things appeared to be attracted by the influence of radiation. They were really warmed, and the current produced caused the appearance of attraction. On trying the same experiment under diminished pressures, this apparent attraction after a time ceased, and then when the vacuum was sufficient, repulsion was observed instead. In this way he was led to the invention of that marvelous instrument, the radiometer, and afterward to the discovery of those extraordinary effects due to what he called radiant matter. I do not know whether I ought not to include the radiometer and several other of Mr. Crookes' pieces of apparatus in the catalogue of instruments for measuring radiant heat. They certainly do measure in a way; in fact, in one of his tubes Mr. Crookes arranged a torsion balance, by means of which he actually weighed the repulsion due to a certain beam of light. The subject of his instrument is itself so vast that I really dare not enter upon it, and I think I am justified, for radiometers do not, as far as I know, supply convenient means of making accurate comparisons of feeble degrees of radiation.

There is no end of the number of instances that might be given of the effect of air currents produced by even feeble degrees of radiation. Every experimentalist must have met with many instances. Though the effects are so strongly marked, I do not think much has been done to make use of these currents to measure radiation. There are the experiments of Mr. Bennet and Mr. Crookes, already referred to; there is also an instrument devised by Joule, and described in the first volume of his papers published by the Physical Society, p. 535, which I cannot do better than describe in his own words:

"A glass vessel in the shape of a tube, 2 ft. long and 4 in. in diameter, was divided longitudinally by a blackened pasteboard diaphragm, leaving spaces at the top and bottom each a little over 1 in. In the top space, a bit of magnetized sewing needle, furnished with a glass index, is suspended by a single filament of silk. It is evident that the arrangement is similar to that of a 'bratticed' coal pit shaft, and the slightest excess of temperature on one side over that on the other must occasion a circulation of air which will ascend on the heated side, and after passing the fine glass index descend on the other side. It is also evident that the sensibility of the instrument may be increased to any required extent by diminishing the directive force of the magnetic needle."*

I have made and now show an instrument of this class, in which the vane consists of a fragment of straw suspended by a quartz fiber one ten-thousandth of an inch in diameter. The arrangement is so delicate that it is in this form quite unusable, but it would seem, as it did to Joule, to be capable of being developed into a serviceable instrument.

Both Joule and Weber make use of the moon, to show the extreme sensibility of their instruments. It was long a question whether any heat was sent to the earth from the moon. Prof. Tyndall, in speaking of this heat, says: "Concentrated by a polyzonal lens more than a yard in diameter upon the face of his pile, it required all Melloni's acuteness to *nurse* the calorific action of the moon up to a measurable quantity." I shall return to the moon's heat in another lecture, and show that this is not really a fair comparison; but it is, I hope, sufficiently evident that, by means of the air current itself, it is possible to detect effects of heat so feeble in amount that nothing but the most delicate apparatus would be thought capable of making their existence evident.

* "Proc. Manchester Lit. and Phil. Soc." Vol. iii., p. 73.

THE MANUFACTURE OF DISTILLED PERFUMES AND ESSENTIAL OILS IN SOUTHERN FRANCE.

THE distillation of essential oils from various species of wild plants, such as lavender, thyme, fennel, romarin, etc., is an important industry in southeastern France. It is described in a recent report from the American consul at Marseilles. The region of aromatic plants is a tract of mountainous country about 100 miles in length by 50 in breadth, which includes part of the department of Drome, Vaucluse, Var, Basses Alpes, and the Alpes Maritimes. It lies at some distance from the coast, Nyons, the center of the distilling industry, being in the valley of the river Aigues, which is the northern limit of the olive in eastern France.

The most useful ones are the lavender and aspic, two plants of the genus labiæ, wild thyme, rosemary, absinthe, rue, sage, origanum, and fennel, which latter grows along the margins of mountain streams. Of these by far the most important is the lavender (*Lavandula vera*), which grows so profusely that the summer winds carry the perfume far over the hot plains below.

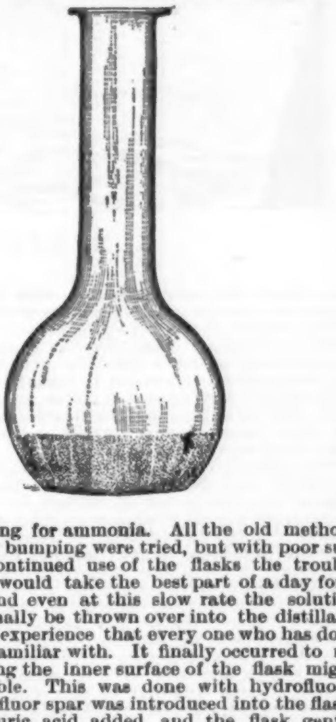
The harvest enlists a large share of the peasant population; and so profuse is the supply, that in good seasons the people who gather and sell lavender to the distillers, at prices ranging from 5f. to 8f. per 100 kilogrammes, are able to earn thereby as much as 4s. a day, wages that are considered munificent in a country of scant employment and ill-requited labor. The distillation of lavender on an industrial scale was begun more than a century ago in the neighborhood of Grasse, which is still the principal mart of production and commerce for finer perfumes of cultivated flowers; but during recent years the business has extended inland and westward until Drome, the most westerly department of the district, now produces 66,000 of the 125,000 lb. of oil of lavender manufactured in the country. In many places lavender, rosemary, thyme, and the other aromatic plants are distilled by farmers and small operators in the villages and communes. The harvest of lavender begins about the 1st of July and continues until the end of September. The best results, both as to quantity and quality, are obtained by distillation of the first plants in the seasons of blossoming, but as these are available only during one quarter of the year, the lavender is dried like hay, and furnishes material for distillation during nine or ten months. The same is true of the aspic (*Lavandula spika*), which is known as "garden lavender," but all are, like the true lavender, at their best when in the season of full flower, which varies according to species from April until the end of summer.

The practical process of distillation varies but slightly for all these varieties, and the same apparatus is often used successively for each kind of plant as its season of flowering and harvest arrives. Three hundred pounds of dried lavender plants, or 220 lb. of aspic, are required to produce 1 lb. of essential oil. The refuse plants are dried and used as litter for stables and manure. In medicine it is employed as an excitant and tonic in the treatment of paralysis, hypochondria, and epilepsy.

The oil of aspic serves measurably for the same purposes, but is a coarser, ranker perfume, and much less valuable than the true lavender, for which it is often substituted. All this class of essential oils, including those of thyme, rosemary, and fennel, vary greatly in grade and consequent value according to season of distillation, the skill and care with which the plants are selected, and the process of manufacture performed. The distillation of essential oils from wild aromatic plants, the manufacture of perfumes from cultivated flowers, and the preparation of preserved fruits by the process of crystallization are three profitable industries peculiar to Southern France. They have been built up, each in its separate locality, and have become practically monopolies for no other apparent reason than because they were first successfully undertaken here, and the world of consumers is content to believe that original brands are best. The same is true of other things, notably liqueurs, such as Benedictine and Chartreuse.

TO PREVENT BUMPING IN DISTILLATIONS.

SOME time ago, while doing some extended work in water analysis, I experienced great trouble, annoyance, and delay from the bumping of the permanganate solu-



tion in distilling for ammonia. All the old methods for preventing bumping were tried, but with poor success. With continued use of the flasks the trouble grew until it would take the best part of a day for a distillation, and even at this slow rate the solution would occasionally be thrown over into the distillate. It was the old experience that every one who has done this work is familiar with. It finally occurred to me that roughening the inner surface of the flask might stop the trouble. This was done with hydrofluoric acid. A little fluor spar was introduced into the flask, a little sulphuric acid added, and the flask gently warmed till action commenced, and then put aside for a short time.

The flask so treated proved a perfect success. The unruly permanganate solution boiled as peacefully and rapidly as could be desired, and I was enabled to make a distillation, in good temper, in an hour, that before the flask was so treated had taken several hours and constant watchfulness. After long use the flask will require a second etching.—*Stanley E. Parkill, in Pharmaceutical Era.*

CAUSTIC SODA LYE, AND HOW IT IS TESTED.

THE causticizing of the liquor obtained from recovered ash in paper mills is perhaps the most important operation connected with the chemistry of paper making, and certainly it is so with the pulp or boiling department of any mill. The paper-making qualities of the pulp made from the fibrous plant with which the caustic soda lye is treated depends to a large extent upon the way in which the causticizing operation is carried out and upon the completeness of the chemical reaction which takes place between the lime and the carbonate of soda contained in the liquors made from the recovered ash.

The operation is too often carried out without due care being paid to the several details connected with it, and without that necessary skill which is so essential to success. In many instances no chemical test is made to indicate whether or not the whole of the carbonate of soda has been converted into caustic soda. The whole process is usually consigned to the care of an ordinary workman, who completes the operation according to his own judgment and in accordance with his own notions as to what is right, and who may imagine he knows all about it. He may know a good deal in his own way, as most workmen generally do who confine their attention to one operation, and who possess any power of observation at all; but where this power of observing the general condition of his work exists, it is usually difficult to convince him of the necessity of performing a simple test to enable him to be perfectly sure that the causticizing of the liquor has been finished or completed as perfectly as ordinary practice will allow. He prefers in many cases to guess at it, and no doubt in the majority of cases does so with a fair amount of precision. Any error he may make is frequently not observed till nearly all the evil, or rather we should say the annoyance, caused by imperfectly causticized liquors in the boiling house has shown itself in the daily work. One or two, or even more in a large mill, of imperfectly cooked boilers of esparto may thus be turned out at any time, deranging the work to an extent quite sufficient to cause a very serious loss of money.

If in any single case the grass does not come out well, the liquor is naturally and almost invariably pitched upon as the evil doer, although, indeed, it may be other things which are causing the trouble. Imperfectly cooked grass must be recooked, which means another dose of caustic soda lye, etc., and when we recollect that somewhere between 6 and 10 cwt. of caustic soda are used to prepare that amount of esparto, which is equal to one ton of paper, the cost of the caustic soda thus consumed is very considerable. If the under-cooked esparto is not treated with another dose of caustic liquor, the strength of the lye is generally increased, so that the proportion of caustic soda to the grass, or the quantity used per cent., also increases.

All these attempts may prove ineffectual in extreme cases, when fresh drum caustic is resorted to as a last resource. Extreme cases are, however, easy to deal with. They are too apparent to miss the observation of any mill manager, but in the case of imperfectly causticized lye the evil may be overlooked or, as above stated, rectified by simply increasing the strength of the lye, and although the grass may then be perfectly cooked; much soda may be saved by bestowing a little care and attention on the finishing of the liquor in the causticizing pans. That is to say, it ought to be completely causticized.

We have already pointed out that the lye made from recovered ash frequently contains sulphide of sodium. This sulphide is not acted upon to any appreciable extent by the lime when in the causticizer, and it is not removed by many of the systems of causticizing prevalent in paper mills. It often exists in the liquor in very considerable quantities, and when such lyes are acidified by the addition of muriatic acid to them, a cloudiness is produced, due to the decomposition of the sulphide by the acid or by other ingredients in the liquor. It will even cause an effervescence when the acid is added to a solution of it in water. When therefore the caustic liquor in the causticizing pan contains sulphide of sodium, and it is desired to ascertain if the carbonate has been transformed into caustic as completely as it is possible under the circumstances which prevail, it is necessary to have a chemical reagent present in the sample of liquor used for examination, so that when the acid is added to it, the sulphide of sodium will not cause an effervescence and thus vitiate the test. The reagent usually employed by chemists for this purpose is either bichromate or chromate of potash. These bodies oxidize the sulphide in acid solutions, and when they are added simultaneously with the muriatic acid to the causticized lye, the sulphide of sodium, if it is present in moderate quantity, is acted upon and oxidized, so that no possibility of an effervescence could take place due to the escape of sulphureted hydrogen. The carbonic acid gas from the carbonate of soda will then escape by itself, and when much more than a slight indication of this is observed, the lye is not finished.

The solution we would recommend for testing the finished operation of caustic liquor is made up by diluting say one pint of strong muriatic acid with half a pint of water containing an ounce of bichromate of potash dissolved in it. The mode of testing is as follows: A small quantity of the causticized lye is taken from the pan and carefully filtered through a double filter paper into a test tube about nine inches long and three-quarters of an inch in diameter, until it is one-half full. This test tube must be perfectly clean, and the lye, when filtered, appear perfectly clear or free from particles of lime which, in the case of bad filter paper, may pass through it with the liquor. The mixture of acid and bichromate is now added, when, if there is any effervescence, due to the escape of carbonic acid, the lye is not perfectly causticized.

There is one point in connection with this test which is worthy of note, namely, the strength of the lye. Many years ago, when chemical testing methods were not so perfect as they are nowadays, carbonate of soda liquors were causticized at a much lower strength than at the present time. The usual strength of the liquor in degrees Twaddell was then about 14°, but now it is much higher. The same volume of liquor at say 28° Twaddell's hydrometer contains practically twice the amount of soda that a liquor of 14° Twaddell contains.

If we take equal volumes of two liquors corresponding to these strengths, and having the same percentage causticity, it is very evident that the liquor of 28° Twaddell will contain twice as much carbonate of soda (as well as caustic) as the other liquor of 14° Twaddell. If new acid be added to each of these, one ought and, in fact, one does get twice as much carbonic acid gas evolved from the one as from the other; so that, while each liquor may contain the same proportion of caustic to carbonate of soda, the higher strength liquor will probably show an effervescence, while the lower strength one may not do so.

This is one of those points or details in testing such liquors which is somewhat overlooked in paper mills, if indeed it is known at all. The probability of committing an error, when testing these lyes, owing to one sample being stronger than another, is perhaps not of great importance, but we have thought it necessary to mention not only the possibility of such a thing occurring, but also a remedy which is not difficult to find.

Always have the caustic lye of the same strength from wherever the lye is obtained, and if this is not so, dilute the same with pure water before performing the test. It must also not be imagined that twice the volume of 14° Twaddell lye will necessarily give the same amount of effervescence as one volume of the stronger lye when the same quantity (or volume) of acid is added to each. It is possible to get a slight disengage-

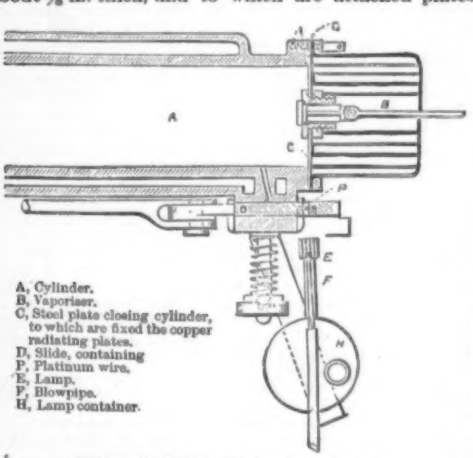
ment of carbonic acid gas in the one case and not in the other—at least in the weaker lye it is hardly perceptible. The carbonic acid liberated by the action of the acid on the carbonate of soda is soluble in water, and in the one case, namely the weaker liquor, there is a larger quantity of water present than in the other to dissolve the carbonic acid gas and prevent it from appearing as gas bubbles.

We have recorded in the above lines, merely the qualitative mode of testing caustic soda lye, and have said nothing with respect to the much more important and valuable method of testing for the amount of soda, both as carbonate and caustic, etc., in a quantitative sense. This requires greater skill and more careful manipulation. The qualitative test is, however, very useful to paper makers, as it shows without any loss of time whether the requisite quantity of lime has been added to the liquor in the causticizer. It may be performed in a few minutes, and if ordinary care be observed in always taking the same quantity of the different batches of caustic lye for each test, and adding a known amount of the muriatic acid mixed with bichrome, it will be equal to every requirement as far as ascertaining whether or not the carbonate of soda in the lye from the recovered ash has been properly converted into caustic. By such a test it is impossible to tell how much lime has been added, and, of course, it is quite useless for finding out whether or not too much lime has been used. This is a much more complicated test, and one which can only be performed by the professional chemist.

Although the qualitative test is very simple, yet there are some paper makers who do not understand how it is performed, and others who do not use the test at all. They may not see the value of it, nor appreciate its importance in the general routine of the mill. Others, doubtless, know of the test and use it constantly, and will then have all the arrangements made for carrying out the test by either the foreman or workman in immediate charge of this department.—*Chem. Trade Journal.*

KNIGHT'S OIL ENGINE.

THE accompanying engravings illustrate an ingenious and simple engine, the invention of Mr. J. H. Knight, of Barfield, Farnham. This engine burns the vapor of paraffin oil in the cylinder. The engine is horizontal. The one-half horse power engine shown in the engraving has a 4 in. cylinder and an 8 in. stroke. The vaporizing chamber, the *Engineer* says, is at the end of the cylinder, which is closed by a steel plate about ⅛ in. thick, and to which are attached plates



A, Cylinder.
B, Vaporizer.
C, Steel plate closing cylinder, to which are fixed the copper radiating plates.
D, Slide, containing
P, Platinum wire.
E, Lamp.
F, Blowpipe.
H, Lamp container.

Fig. 2—KNIGHT'S PETROLEUM ENGINE.

somewhat like the ribs of a Gurney's stove projecting into the vaporizing chamber. The latter and part of the cylinder and lighting side are shown in the sectional view, Fig. 2. Under the vaporizing chamber is a paraffin heating stove for preliminary heating. This heats the chamber to a considerable temperature, and, when it is hot enough, which is in ten to fifteen minutes, a small quantity of oil is pumped into the chamber by a small pump—not shown in the engraving. Some of this is immediately vaporized, and on the flywheel being turned by hand it is sucked into the cylinder, fired, and motion given to the moving parts. The air and oil enter together by the vertical pipe at the after end of the engine. The heating lamp is extinguished when the engine has got well to work. Vapor of paraffin oil is more difficult to ignite than gas or benzoline vapor. The igniting slide, which is of very small dimensions, contains in a hole a spiral of platinum wire. This is exposed to the flame of a paraffin oil lamp, a high temperature flame of the blowpipe kind, the air blast for which is made by the bellows fixed on the after end of the bed plate under the cylinder. At the proper moment, the platinum wire, which is kept at a white heat, is, by the motion of a cam, drawn into communication with the compressed charge of vapor and air. The slide, although intermittently exposed at one end to the heat of the blow-pipe, wears remarkably well. In one engine, which has been in daily use for a year and a half, the slide has not been refaced or scraped up during that time. The soot and oil vapor appear to act as an excellent lubricant. The oil is pumped into the chamber by a diminutive force pump, worked by the engine. It is on the right hand side of the cylinder.

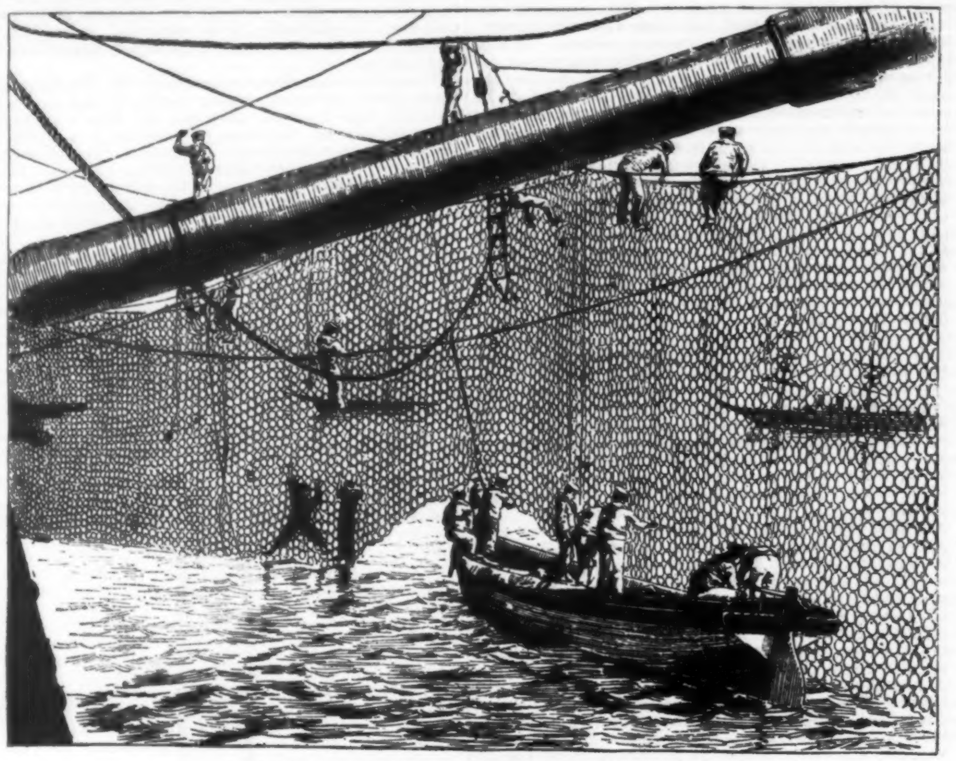
The engine is on the three-cycle system, the same as the Griffin and Beck gas engines. The great advantage of this system for oil engines is that as the exhaust is completely cleared away from the cylinder the charge of vapor and oil is more readily ignited. The governor acts in a twofold manner, first by stopping the supply of oil to the vaporizing chamber, and by preventing the valve connecting the cylinder and vaporizing chamber from opening, so that an explosion is missed. The cylinder is water-jacketed, the water circulating as in gas engines. No oil is required in the cylinder; a small quantity of the vapor condenses at each stroke, and acts as a lubricant. The slide requires a small quantity of oil. The one-half horse power engine runs 300 revolutions per minute, and gives 0·8 to 0·95 horse power on the brake, according to the quality of oil used. If a suitable oil is used, a brake horse power requires, we are informed, one-fifth of a gallon of oil per hour. The igniting lamp burns about a pint and a half in the day. The oil used is ordinary paraffin or kerosene oil, such as is used in all parts of the world for illuminating purposes, and which, according to the requirements of the petroleum act, does not give off an inflammable vapor at a low temperature.

One of these engines was very favorably noticed at the Windsor Show of the Royal Agricultural Society.

KNIGHT'S PETROLEUM ENGINE.

RIGGING TORPEDO NET DEFENSE.

THIS illustration is from a photograph taken on board the Iron Duke, an ironclad of Admiral Baird's



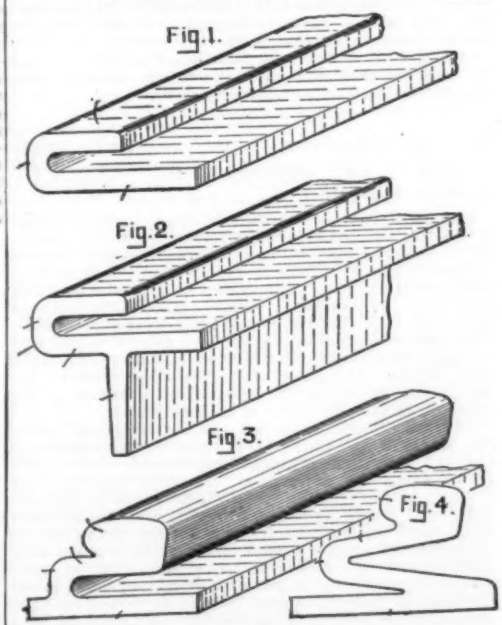
RIGGING TORPEDO NET DEFENSE.

fleet. The nets are topped up so as to admit of lacing together of the separate nets, each of them 10 ft. by 15 ft. They are made of steel wire grummets, connected by small rings of steel, the booms being about 40 feet long. When all are laced together, the booms are lowered until the tops of the nets are just above the water. —*The Graphic.*

SPRING RAILROAD RAIL.

THIS device is by Hosea W. Libbey, Boston, Mass. The object is to produce a rail in which there will be a certain amount of elasticity.

In the simplest form of rail, as shown in Fig. 1, a



sheet of metal of the required length and width is bent into a J form, as shown, the wide portion forming the bearing surface to rest upon the sleepers, the car wheels running upon the narrow or tread portion. It will be seen that there is a space between the parts, so that as the car travels upon the rail portion it is free to give or bend, the back part of the rail acting as a spring, thus materially preventing jolting and causing the car to run more steadily. Figs. 2, 3, 4 show modifications which will readily be understood.

ONE great fault of humanity is a propensity to talk too much; it is as fatal to a man's success and prosperity as to undertake to do too much. It is infinitely better to keep silent and look wise as an owl than to talk much and appear like an ass.

LOCOMOTIVE PRACTICE IN AMERICA.

By AN AMERICAN ENGINEER.

JUDGING by the appearance of every locomotive on this continent, there seems to be only one position in which it is possible to place the cylinders, and that is outside the frames. Such an obsolete machine as an inside-cylindered engine is never seen here, its use having been discarded in the earliest days of locomotive building in America. There were two good reasons urging this departure from English practice: one being the difficulty and cost of obtaining crank axles, this difficulty being at that time much more formidable and costly to overcome here than in England; the second reason was that the extent of country and scarcity of trained labor necessitated the building of locomotives in the simplest manner and with all the working parts easily accessible, so that the engine drivers could keep the engines running as long as possible without the assistance of a locomotive machine shop. Outside cylinders gave the accessibility, and also made the use of the parts and the method for repairing them more easily grasped by men with little experience or training on a locomotive; and in this position they have given such entire satisfaction that it would be absurd to change it in the present state of the art of locomotive design. American engineers have become so accustomed to placing the working parts in full view, that all designing is now done with the idea "accessibility of parts" constantly in mind, and this idea is often carried to extreme lengths.

There is very little difference in the design of the cylinder barrel, ports, etc., in the two countries, except so far as the different location of cylinders and steam chests makes a difference imperative; the metal is the same thickness, steam passages and clearances about the same, but the ports are made longer here, and with advantage. The general plan of the cylinders used varies considerably; some are like engravings Figs. 1 to 6, consisting of two separate cylinders and a distance piece between the frames, forming a saddle on which the smoke box rests.

Another plan, shown by engravings Figs. 7, 8, and 9, and most generally followed, is to make two castings only, each casting forming one cylinder and half the saddle, the two being bolted together in the center of the engine. This design makes a more rigid connection than the former between the cylinders themselves and between the cylinders and the frames, and also avoids a number of steam-tight joints between each cylinder and the saddle, which are necessary in that design.

Perhaps the only reason for using the three castings at the present day is the cheapness to repair should any disaster overtake either cylinder, as it would not then be necessary to replace so large a casting. There is nothing special or novel about these designs. An effort to design the cylinder so as to fit either side indiscriminately is usually made. Care is taken to make all steam and exhaust passages of ample size, and the passages are so disposed that the steam will not produce fracture by expansion of their walls—a trouble which has often arisen.

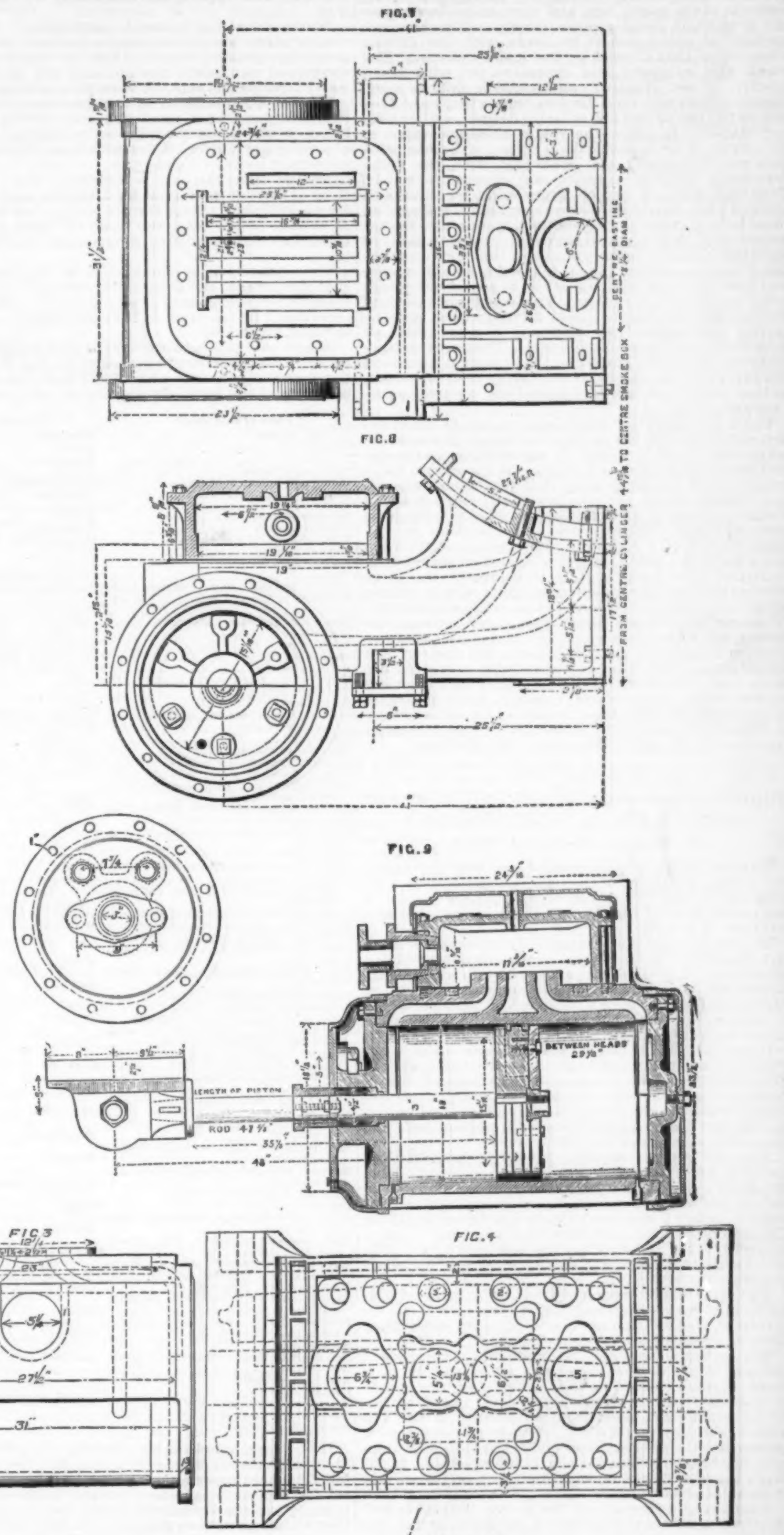
One difference from English practice quickly noticed is the small number of bolts considered sufficient to make the joints of cylinder and steam chest covers; this practice has nothing whatever but cheapness to recommend it, and, combined with the use of tallow as a lubricant, it often gives a great deal of trouble through leaky joints. These leaking cylinder cover joints have caused a great diversity in the method of making them. When there is no obstruction to prevent the cover being moved circularly on its seat, the studs are removed, the faces ground together, and the joint made with red lead, boiled oil, or black japan; some use copper wire or other material such as asbestos without grinding, but the process of facing up with a scraper so familiar in England is never seen here, it would be considered too slow.

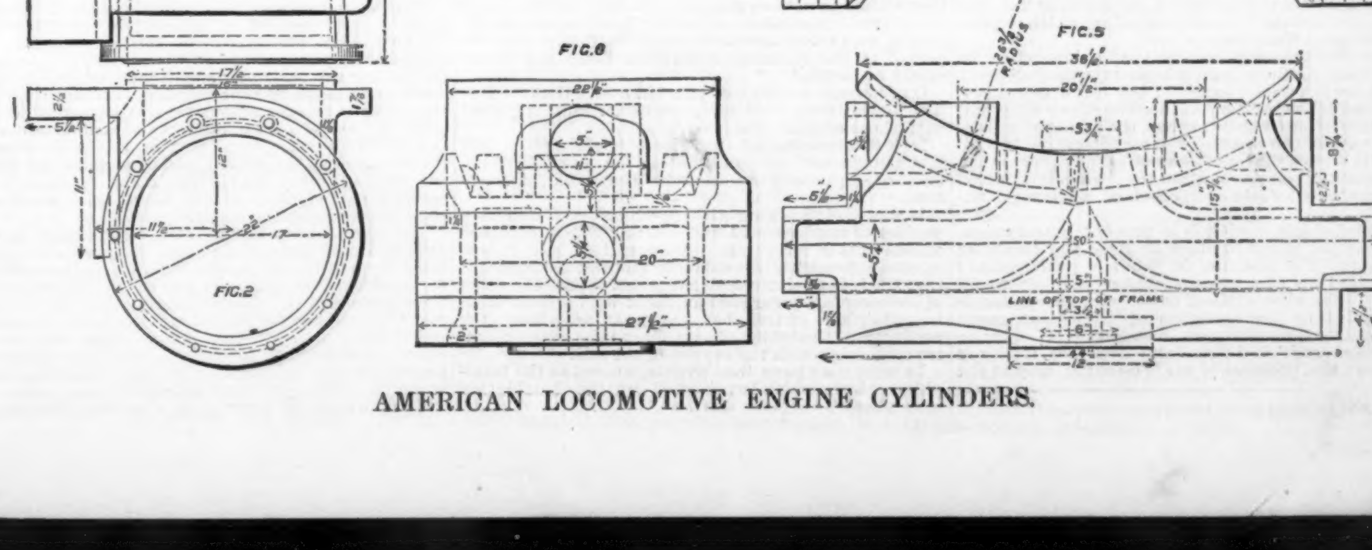
Copper wire is the material always used for making the steam chest joints, because it is so universally successful.

The method of making the joints of steam pipes to cylinders, etc., is much cheaper and better than the English method of scraper-faced joints; they are always made with what is known as a "ball and socket" joint. They are machined to shape with specially made tools, then ground together, and two bolts only are required to hold them perfectly tight, the whole joint being made or re-made very cheaply indeed.

These joints on the cylinders have another advantage in allowing the use of cast iron steam pipes, any small difference in length or angle of pipe being easily taken up by them.

In England a great many objections have been urged against the use of outside cylinders; and, possibly, with the locomotive as made in England years ago, these objections had great weight; but it would





AMERICAN LOCOMOTIVE ENGINE CYLINDERS.

be hard indeed to find anything serious to urge against using them as they are used on the American locomotive. And, judging by the designs of compound engines which are brought forward, it seems very likely indeed that all objection to their use in England will gradually die out. They are very easy to get at, do not give any trouble by corrosion from the contents of the smoke-box, and they undoubtedly permit a cheaper, simpler, more direct, and much more mechanical connection to be made with the driving wheels than that allowed by the inside cylinder. The crank axle, so heavy and expensive, yet so untrustworthy, is not required, and there is not so much danger consequent on a broken connecting rod; they permit the use of any size cylinder desired, without being compelled to place the steam chest and valves in an awkward or undesirable position, and make slide bars and everything else connected with the cylinders much easier to examine and cheaper to repair. That they make an engine larger and look clumsier is allowed; but nearly all other objections urged against them have no value. In America it would not be admitted that they make an engine unsteady or liable to leave the track, nor can any one show that they do so unless a large amount of play is allowed around the axles and axle boxes through neglecting to adjust the wedge horn blocks, etc., for wear. The bar frame so rigid transversely, the well-balanced driving wheels, and the perfect arrangement of springs, does away with all such objections to outside cylinders. They are certainly more exposed when placed in that position; but that the exposure does any harm has hardly been suggested, as they are always carefully lagged and covered to prevent radiation.

The steam chest is always placed on top of the cylinder, which position has many advantages; it is so easily taken down that it makes it exceedingly convenient and cheap to examine and repair the valves and valve seats, but, on the other hand, it is very much exposed, and, strange to say, there is hardly any effort made to clothe it properly, so that there is undoubtedly great waste of steam in consequence. This position necessitates the use of a rocker or intermediate shaft when using the link motion, but this is not regarded here with the same hostility it is in England; the large bearing surfaces now used in connection with it destroy all irregularities, and the results are quite satisfactory. Of course, if the steam chests were placed between the frames, the rocker arm would not be required, and this position would very materially lessen the waste of heat by radiation; but then it necessitates a greater distance from valve seat to cylinder barrel, and therefore entails really more waste through large clearance spaces, besides which there would be somewhat greater difficulty in examining and making the necessary repairs to valves and valve seats.—*The Engineer.*

PURIFICATION OF SEWAGE AND CONTAMINATED WATER BY ELECTROLYSIS.*

By WILLIAM WEBSTER, F.C.S.

THE increasing populations of our large towns has made the question of sewage purification a very pressing one, particularly in relation to the purity of our rivers, most of which unquestionably are in a serious state of pollution.

The sewage question generally has become of such importance in reference to public health now and hereafter that it is evident steps must be taken as quickly as possible to remedy the present condition of things, and to maintain as high a standard of purification as is compatible with the enormous quantities with which we have to deal.

It may be that the present scientific knowledge is not sufficient to entirely and finally deal with this question. We should, however, aim at as high a standard of purification as possible—it is of no use to try half measures—and; whatever the treatment may be, my contention is, that the nearer nature's action is approached, the nearer the solution of the difficulty.

Any new process requires thorough investigation, and it is for this reason that my experiments have taken up so much time; the success of certain laboratory experiments having been made public quite eight months before I was able to start a series on anything like a working scale, and since that time my connection with other undertakings has rendered it very difficult for me to concentrate attention except for short periods at intervals.

The oxidation of organic matter can only be attained by one mode—chemical action—whether it be by filtration, the addition of chemicals, or by mechanical force represented by the electric current.

Sewage is a most complex compound, the component parts of which depend upon the water supply of a town, in some cases upon the rainfall and the industries of the locality. Householders and owners of factories would much assist local authorities in the end aimed at if they would disinfect their refuse before it passes into the sewers. Thus one of the most objectionable features I have noticed in London sewage is the large amount of organic matter floating on the surface with an obnoxious odor.

I am not quite certain of its source, but it is evidently of a nature that points to gas works or tar distilleries, also certain dyes and tan refuse which require more treatment than sewage itself.

I know that the manufacturer is at a loss where to put his waste products, and it is an extremely difficult question for the public to solve; but it is a moral certainty that, if the sanitary authorities of our cities and towns have to purify their sewage, the taxpayer will decline to pay for the treatment of manufacturers' refuse when it is known that sewage alone requires very much less expenditure on purification than when it is mixed with complicated waste compounds of a chemical nature.

The great object in view is to prevent putrefaction, and it may not be out of place to state the means of arresting it. The question is, What is putrefaction? Putrefaction is a spontaneous change common to all organic bodies when exposed to the air; the action is accompanied by the evolution of unpleasant gases, which are, for the most part, compounds of sulphur and phosphorus; it differs from decay, as it is not oxidation; the presence of air is essential only at the commencement of the action, and not after it has fairly set in.

Modern science teaches us that air may be the carrier of ova which induce the change. Any dry matter does not putrefy; intense cold prevents putrefaction.

The atmosphere acts mechanically by its power of removing foul vapors, and chemically by their oxidation.

Water—its action is largely mechanical. Thus in a river organic matter becomes separated, and oxidation takes place by reason of the air dissolved in it; showers of rain purify the air, and the molecules of water forming the rain act as carriers of oxygen.

The soil as manifested in our graveyards, the iron oxides in the soil acting as purveyors of oxygen, and owing to the porosity of the soil, cause the oxidation of putrefying matter. Intense heat and light also play important parts in disinfection.

Sewage farms can only be successful when the porosity of the soil is adapted for filtration, and when the area is sufficiently large for the work it has to do; but all sewage before being run upon the land should be treated so that secondary putrefaction cannot be set up.

The organic matter should also be disintegrated so that the pores of the natural filter shall not be blocked up by it when in a state of semi-solution. Greasy matters should be removed, as they also have a tendency to block up the soil.

Before entering into the particular subject of my paper, I must ask you to glance at the list of a few of the chemical processes which have been tried in various parts of the world during the last 120 years.

Name of substances.	Inventor.	
Sulphate of iron	Deboissieu	1762
Chlorine	Halle	1785
Lime	Estienne	1802
Powdered charcoal	Girand	1805
Chlorine and chloride of lime	Guyton Morveau	1805
Ashes	Chaumette	1815
Sand	Duprat	1818
Sulphate of iron	Briant	1824
Chloride of soda	Labarraque	1824
Waste chloride of manganese	Payen and Chevalier	1825
Sulphate of lime	Siret	1827
Animal charcoal	Frigerio	1829
Peat	Guibourt and Sanson	1833
Charcoal and calcined marl or river mud.	Pottevin	1836
Sulphates of iron and zinc with tan and tar	Siret	1837
Earth, lime and waste substances.	Rossier	1837
Peat ashes	D'Arcet	1840
Metallic oxides and carbon	Krafft and Sncquet	1840
Chloride of zinc	Sir William Burnett	1840
Schist coke	Hompesch	1841
Trade refuse, charcoal, and ashes	Albert	1842
Powdered lignite	Jourdan	1843
Impure alum	Siret	1843
Sulphate of zinc, charcoal, and clay	Gagnage and Regnault	1844
Persulphate of iron	Baronnet	1845
Schist coke	Du Boisson	1845
Chlorides of iron and zinc	Dubois	1846
Lime and precipitating tanks	Higgs	1846
Nitrate of lead	Ledoyen	1847
Waste salts of iron, lead, zinc, etc., with pyrolig. matters, ashes, etc.	Brown	1847
Pyrolignate and perchloride of iron	Ellerman	1847
Impure chloride of manganese	Young	1847
Dried seaweed, lime, and sulphate of lime and zinc	Salman	1848
Peat charcoal	Rogers	1848
Charcoal, soot, mineral salts, etc	Legras	1849
Spent tan, carbonized	Tarling	1850
Fresh bark, sulphate of iron, and peat charcoal	Angely	1850
Metallic sub-salts, as of iron, alumina, etc.	Browne	1850
Milk of lime and collecting the deposit	Wicksteed	1851
Acids and metallic salts, and filtrations through charcoal, clay, peat, gypsum, etc	Dover	1851
Lime, sulphates of alumina, and zinc and charcoal	Stothert	1852
Lime, magnesian earth, sulphate of zinc or iron, and vegetable charcoal	Gilbee	1852
Sifted ashes, breeze, or peat charcoal	Perks	1852
Sulphate of zinc, potash, alum, and sand with waste tan, ashes, lime, soot, etc	Pinel	1853
Metallic sulphates, metallic chlorides or charcoal and magnesian salts	Herapath	1853
Salts produced in working galvanic batteries	Dering	1853
Peat or bog earth containing salts or oxides of iron	Dimsdale	1853
Peat and other charcoal and chloride of sodium, etc	Macpherson	1853
Animal charcoal, alum, carbonate of soda, and gypsum	Manning	1853
Magnesia and lime with sulphurous and carbolic acids	Smith and McDougall	1854
Lime and finely divided charcoal	Wicksteed	1854
Boghead coke	Herapath	1854
Soft sludge from alum works with lime and charcoal	Manning	1854
Peat charcoal carbonized with oil of vitriol	Longmaid	1855
Alum schist or shale, and other aluminous minerals, with lime and charcoal	Manning	1855
Manganates and permanganates	Condy	1857
Superphosphate of lime with magnesia and lime	Blyth	1858
Sulphate of iron with lime in solution (recommended only), etc	Letheby	1858
Spongy iron	Bischoff	1865
Iron finely divided in revolving cylinders.	Anderson	1884
Iron sulphate Aluminum sulphate Calcium sulphate Magnesium sulphate Silica Black oxide of iron	Named ferrozone.	1887

It is, I fear, true that many of the methods enumerated, and most of those not enumerated, have not only failed to meet reasonable expectations as to their physical and sanitary characters, but they have only proved in many cases costly failures; and it is a remarkable fact that claims have been made within the last five years in reference to sulphate of iron by itself, or in combination with other materials, as if it had only just occurred to the chemical mind that these substances ought to be tried.

On reference to this list, you will notice that the first five, dating from 1762–1805, are practically identical with those of recent date.

In 1843, alum seems to have been tried, and in 1857 manganates and permanganates; the latest development of sulphate of iron is under the name of ferrozone.

It was while working with perchloride of iron as a purifier of sewage that I first learned the importance of iron salts in relation to organic matter, and it was in connection with this chemical and free chlorine gas that the idea of electrolysis suggested a possible mode of treatment of water contaminated with organic matter. Sulphate of iron has one great drawback—the production of sulphide of iron, due to the organic matter combining with the oxygen of the salt.

In nature we have iron pyrites, known as the bisulphide of iron, which is produced by the deoxidation of sulphate by organic matter.

The sulphureted hydrogen in sewage is entirely due to the same action on the sulphates contained in it. It therefore follows that sulphates should not be added, as they only increase the nuisance instead of abating it. Sulphuric acid added to manganate of soda and run immediately into the sewage is sure to lead to objectionable reactions. The very fact of adding chemicals means adding water; thus, to a certain extent, producing a seeming purification. The following illustration will show this:

Ten grains of lime added to a gallon of sewage in the form of lime water means the addition of one pint of water, it therefore makes an apparent purification of 12·5 per cent. by this increase of water.

I have here a list of analyses taken from the appendices of the report of the Royal Commission on Pollution of Rivers. My experience being that lime produces after-putrefaction if used alone or with sulphates, and if used in large quantities is also sure to set up after-precipitation when the resulting effluent is run into river water.

I have already stated that putrefaction means sulphureted hydrogen. On the west coast of Africa the water contains large quantities of sulphureted hydrogen, its formation being due to the presence of organic matter and sulphates. I believe I am right in saying that this particular portion of the African coast is known as the sailors' death trap.

Of artificial disinfectants chromic acid is the strongest, sulphurous acid the weakest among mineral acids. Permanganates oxidize dead organic matter under certain conditions, but unless in very concentrated solutions, have little or no action on disease germs. Chlorine gas or oxides of chlorine are the most powerful disinfectants.

The fact that water is easily decomposed provided the current of electricity is of sufficient intensity, and also that the effects produced are precisely in accordance with the chemical equivalents of the substances electrolyzed, is practically the explanation of the whole system; for the chemical changes that take place in sewage when it is electrolyzed depend chiefly on the well-known action that sodium, magnesium, and other chlorides (which are always present in sewage) are split up into their constituent parts. Thus we have at the positive pole chlorine and oxygen set free, and these elements are liberated in a nascent state, a condition in which they are intensely active, so that the organic matter in the sewage is rapidly oxidized into innocuous compounds. So rapid is this action that, provided the sewage contains a sufficiency of chlorides, it is possible to produce a disinfecting fluid from it consisting of oxides of chlorine.

As mine is an artificial action I will take the two disinfectants which are formed in my process, iron oxides and chlorine. The first a purveyor of oxygen, the second, in the form of hypochlorites or chloric acid, absolutely destroys organic matter, living or dead. By using non-oxidizable plates, such as carbon, for positive pole, and iron at the negative pole, with a porous diaphragm between them, I am able to collect the component parts of the mineral salts; therefore, at the non-oxidizable plate I obtain a solution of chlorine and oxide of chlorine, and at the negative plate I obtain ammonia, soda, and potash, which in their turn precipitate any lime and magnesium salts that may be present in the liquid. So strong is the action of oxide of chlorine that it is only one form of carbon plate that will resist disintegration.

My first experiments carried out in this manner were conducted with platinum plates, but the experience was that the cost of platinum put it out of the question, besides which there was a very slight action on the positive plate which distinctly pointed to its ultimate destruction, there being no precipitation of the matters in suspension. By means of an arrangement which consists of a porous pot with a non-oxidizable plate, such as carbon, for the positive electrode, and iron plates for the negative electrodes, I am able to manufacture the before-mentioned solution of oxides of chlorine from brackish sea water or sewage.

The water of the River Thames, near Barking, is admirably suited for this purpose. It is possible that an objection may be raised that the resistance of the porous pot to the electric current would be so great that the cost would render it an impossibility from a commercial point of view, but the very fact of using salt water balances the extra resistance caused by the porous diaphragm, and for every ampere of current that is used per hour I produce 18 grains of nascent chlorine, or an equivalent of the oxides of chlorine.

My experience of nascent chlorine as a disinfectant is that about one-third of a grain is capable of disinfecting one gallon of London sewage (first removing the matters in suspension), and on examination the presence of nitrites is detected, which shows how far the oxidation has been carried. This action, combined with the treatment with iron plates, hereafter described, will, if carried far enough, absolutely eradicate all organic matter. And here it will be as well to mention that the resulting effluent must not have an acid reaction, otherwise fungoid growths appear on the surface after a few hours.

The forms in which these apparatus are best applied on a small scale, with porous diaphragms, are as follows:

First, an outer vessel, which may be made of iron—the sides in that case acting as negative electrodes—and an inner vessel containing the carbon electrode. By means of a siphon connected with a reservoir or tank, containing say sea water or salt and water, the inner vessel can always be kept supplied with the saline solution, and by an easy automatic arrangement it is possible to draw off a given quantity of disinfectant solution when formed. By placing an oxidizable plate in the same pot as the carbon, and connecting the two to the positive pole of the current, I can produce a hypochlorite or chloride of the metal used, which will thus further assist the resulting action.

The many uses to which these disinfectants can be applied I need not enlarge upon. Six small cells of the latest form of the Leclanche type are quite sufficient for producing the necessary power for making two or three gallons of the chlorite solution during the day, and they will last for several months without recharging, it being understood, of course, that they do not remain continuously in action. The apparatus on a large scale may be variously modified according to the strength of the solutions of chlorides acted upon.

By applying the current to a carbon filter as ar-

* Read before the British Association, Newcastle, 1889.

ranged for, Fig. 1, I am able to oxidize the organic matter in water. The positive pole being the porous carbon block, the nascent oxygen produced in the pores of the carbon by the electric current absolutely destroys the organic matter; bacteria being killed and the filter block itself kept clean. The action of porous carbon by itself is due to its power of absorbing noxious gases and effecting their destruction by bringing them into contact with atmospheric oxygen; but it is absolutely essential that there should be a free supply of air; how much more active the action is when nascent oxygen, and even chlorine, are constantly supplied to the pores of the carbon by means of the electric current can be easily imagined.

As an example, the following analysis before and after action may be of interest:

FILTER EXPERIMENT ANALYSIS.

Parts per Gallon.

	Appearance.	Odor.	Oxygen required to oxidize the organic matter.
Before action—dilute sewage...	turbid	bad	0·93
After action—Nitrites present.............	clear	none	0·17
Before action — Contaminated water....	slightly turbid	slight	0·06
After action — Contaminated water....	clear	none	0·00
Before action—Dilute sewage............	turbid	bad	0·82
After action — Ordinary carbon filter..	slightly turbid	slight	0·4
After action—Electric filter....	clear	none	0·13

Current used 0·5 ampere.

For the purposes of this filter, an ordinary form of stoneware, divided so that the lower compartment contains rather more than the upper, is used; a carbon block is fixed in the usual position, and round this block two pieces of asbestos twine are tied; at the top of the block a platinized screw terminal is fixed; this forms the positive electrode. For the negatve electrode, carbon rods are arranged so that they press on the asbestos twine; they are all connected together by means of a carbon disk at the top, also provided with a screw terminal, or, instead of the rods, a carbon cylinder may be used.

All that is required is to attach these terminals to the respective terminals of a battery, consisting of three Leclanche cells arranged in series. The action is automatic, as when the top compartment is full the battery is in action, when empty it is at rest.

On a large scale I have the filter arranged somewhat in the form of Fig. 3, alternate layers of small coke free from sulphur are separated either by layers of sand or perforated tiles; by suitable connection these beds of coke form positive and negative electrodes; the first layer of material being sand, so as to mechanically separate matters in suspension. It is impossible for disease germs to propagate, owing to the nascent oxygen and chlorine produced when the filter is in action.

Another form is by embedding non-oxidizable plates in sand with or without porous diaphragms. The necessary electric current in this case would, of course, be taken from a dynamo. For the treatment of sewage it is absolutely necessary that precipitation of the matters in suspension should take place, and the more complete this is, the better the ultimate result.

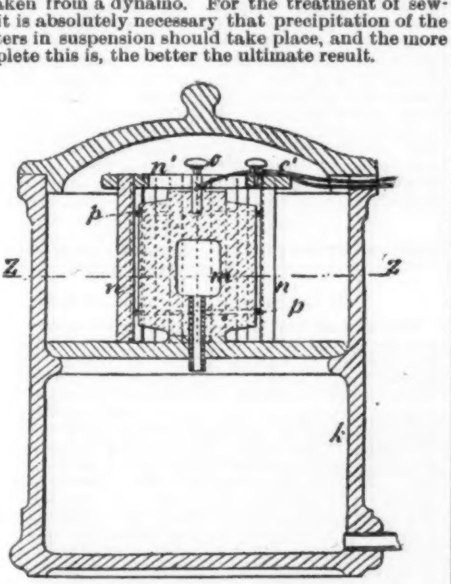


FIG. 1.—HOUSEHOLD FILTER.

c' shows wires to battery; *m*, positive electrodes; *n n*, negative electrodes; *p p*, non-conducting strips; *k*, containing vessel.

To produce this I employ oxidizable plates of such material that they shall have no poisonous after effects either on land or in rivers. The metals should be either aluminum or iron, but the first named is out of the question owing to cost, and then iron, besides having the advantage as regards price, in the form of oxide has many valuable qualities, one of the chief being that sulphureted hydrogen cannot exist when ferrous or ferric oxides are present. It is well known that oxide of iron in the hydrated form is largely used for purifying coal gas from sulphureted hydrogen.

The electric action is easily explained practicably (experiment shown of action of small iron plates connected with a battery, two plates being positive and two negative; sewage acted on in cylindrical glass vessel). At the positive pole the chlorine and oxygen given off combine with the iron to form a salt which, I am persuaded, is, for the moment, a hypochlorite of the metal, but it immediately changes into a chloride, which in its turn is deprived of chlorine to form ferrous carbonates and oxides. During the chemical action carbonate of iron exists in solution, and its formation is due to the presence of carbonates in the sewage, chiefly carbonate of ammonia. In samples that are absolutely free from dissolved oxygen, the ferrous oxide in the white form is precipitated, and on shaking up with air it changes to the usual pale green color; the carbonate of iron at the same time being oxidized, the ultimate precipitate is red, known as ferric oxide (Fe_2O_3), and I have noticed that sometimes this changes after a time back again to the ferrous state, FeO, thus showing that it has acted as a carrier of oxygen to the organic matter present.

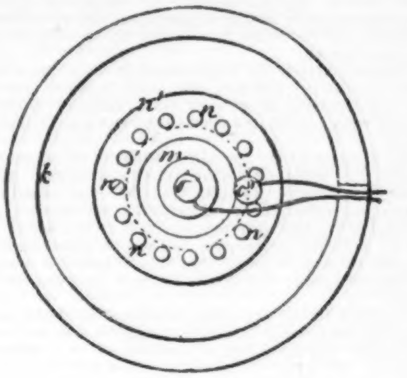


FIG. 2.

On a small scale the precipitate is carried to the top, due to the bubbles of hydrogen collecting round the particles of matter in suspension, but it ultimately sinks in the usual manner. In practice the precipitate does not rise, owing to the larger evaporating area, which allows the escape of the gases produced. The current required for the action varies with the nature of the sewage; but in this case I am using an ampere of current, and the amount of sewage is one-eighth of a gallon. It is usually assumed that 1·5 volts are required for splitting up water into its component parts; this may possibly be true with carbon plates, but with iron plates acting on sewage I can obtain the same result with 0·9 volt, as with double the intensity—of course, it takes a longer time, for with such a low voltage the quantity of current is small.

An ordinary sample of sewage requires, on an average, one ampere of current for ten minutes per gallon, but when mixed with foreign matter such as manufacturers' waste products, the amount required can only be estimated by experiment. The small plates I used in the experiment are of wrought iron; on a larger scale I use cast iron of the commonest "pig" quality, which is only one-third the cost and has the virtue of not scaling.

Most of my experiments have been carried out with wrought iron sheet, which has the disadvantage of scaling, but on account of its lightness is more suitable for experimental work. The plates themselves should always be kept under water, so as to prevent the formation of the red oxide on the surfaces, and the action should be continuous as far as possible, for if continuous the plates seem to acquire some property which reduces the resistance to the electric current, and therefore lessens the cost. At the beginning of a month's run which lately took place, the voltage measured across certain plates was three, but after a few days only 1·79, and doing the same work. On examining the plates freshly taken from the liquid they were in, I found a thin coating of the black or magnetic oxide of iron, which has the property of preventing the rusting of the plate under water when the electric current is cut off.

For 1,000,000 gallons sewage flow, twenty-four hours, the complete plant necessary is: Engine, dynamo, and boiler house; two engines and boilers, each twelve horse power nominal; two dynamos, brick shoots with culverts at side, two settling tanks, sludge tank, sewage culvert, treated sewage culvert, cast iron plates, copper conductor, measuring instruments. Where the effluent has to run into a small stream or river, a suitable tank would have to be constructed for arranging the electric filter as before described.

A channel is kept at the bottom of the electrodes for the silt to collect, with a culvert at side to flush it into so as to prevent any block occurring, but the advantage of this is obvious. The plates in each section are about an inch thick, and can be of any length up to six feet; it may be possibly objected that a large number of plates is required. This may be so, but the larger the number of plates, the less the engine power required, and the longer they last. In each section the electrodes are in parallel, and any one section is in series with the other, the arrangement being exactly like that of a series of primary battery cells.

By actual experience I have been able to prove that at least twenty-five sections of electrodes should be in series, and across any one of these sections the potential difference need not be greater than 1·8 volts, the current being of any desired amount according to the surface of plates used. In experiments that were lately carried out I used a current of 370 amperes, which was calculated as 0·23 ampere per gallon per hour; or, taking it in watts, the estimated horse power required per million gallons in twenty-four hours was twenty-three.

The organic matter in solution of the particular sewage acted on on this occasion showed a reduction of sixty-one per cent. after treatment. The plates, even at half an inch apart, show no signs of blocking; the liquid to be acted on of course should be screened in the usual way and allowed to run through the plates as rapidly as the treatment required will allow, so that every molecule shall come into contact with the surfaces of metal.

During a run that lately took place the measurement across the electrodes proved that nineteen estimated horse power was required to treat 1,000,000 gallons in twenty-four hours, the resulting purification of organic matter in solution amounting to an average of fifty per cent., the waste of the iron plates showing an average of two grains per gallon of sewage treated.

In putting down plates for the above quantity of sewage I should allow sufficient weight for five or ten years' consumption; what remained of this could be sold as "old iron" at the end of that time. One of the advantages of having the plates in series is that if anything goes wrong in any particular section it can easily be set right, the current being cut off during the repairs. The shoot containing the electrodes should be coated inside with some sort of asphalt, so as to prevent, as far as possible, any leakage of current to earth, the asphalt acting as a sort of insulator. The highest efficiency would be obtained by using direct driving, provided that the engine is of first rate workmanship, and the dynamo constructed to run at a comparatively low speed. This saves in transmission, and prevents any difficulty that might arise with belting.

Consumption of coal under the best conditions may be taken to range from 1·8 to 2·5 lb. per horse power hour; the cost of fuel and iron varies so much in different districts, the prices in London being nearly double those near mining localities, that I leave the question of an accurate estimate open; discounting this, it may be taken that the capital outlay necessary for complete plant, and capable of dealing with the sewage of a small town, amounting to a flow of 1,000,000 gallons daily, would be about £6,000 or £7,000, the engines and dynamos being in duplicate, as I presume most engineers would agree they should be. The quantity of iron plates included in the above sum would be serviceable for ten years as far as one can foresee, and I am also assuming that the town where this plant would be erected has no appliances for treatment, such as precipitating tanks, etc.; where these are already in existence, the cost would naturally be less. In reference to the cost per million gallons, the same arguments hold good as to the situation of the town ruling the price. Since my first calculations were made the rise in the markets has increased the cost of working, but it can be arrived at by the average consumption of iron and the necessary horse power. Thus: the daily waste of iron may be taken as 286 lb. and the consumption of coal three-fifths of a ton; the labor required for working a plant of this description would be two shifts, two men to each shift.

By combining the treatment of sewage flowing between metal plates with the electric filter it is possible to produce any degree of purity required. In this case the sewage, after action with the iron electrodes, is allowed to flow into a settling tank, and after remaining there for an hour for the precipitate to subside, the effluent is passed through the filter, any oxide of iron that may be present tending to keep the top layer of filtering medium free from any objectionable action, and in turn forming a filtering medium. As the filter consumes no material, and does not require any additional engine power, for in using it the electrolytic action with metal plates not being carried so far, the cost of its working need not be considered. When a sufficient amount of oxide is deposited on the top layer of sand it can be removed, allowed to dry, and sold to gas works. The resulting sludge contains six per cent. of iron oxide, which does not represent the waste of the plates alone, for in London sewage the wear and tear of the tires of wheels, horses' shoes, etc., in the street means oxide of iron in its composition. One sample taken some months back contained no less than six grains of iron oxide in the gallon before treatment.

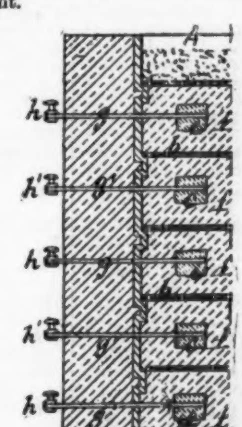


FIG. 3.—ELECTRIC FILTER ON LARGE SCALE.

Layers of Coke may be of any desired surface.

A, sand; B, tile with perforations or thin layer of sand; *c*, carbon electrode; *f*, coke; *g'*, carbon electrode; *h'*, carbon electrode; *i*, channel for filtered liquid to run out, which may be filled with hoggin or large pebbles if desired.

Sir Henry Roscoe has kindly consented to my quoting a few extracts from his report, and the analyses made by him during the investigation of this process. He states:

"The quantity of sewage operated on in each experiment was about 20,000 gallons.

"The reduction of organic matter in solution is the crucial test of the value of a precipitating agent, for unless the organic matter is reduced, the effluent will putrefy and rapidly become offensive. I have not observed in any of the unfiltered effluents from this process which I have examined any signs of putrefaction, but, on the contrary, a tendency to oxdize.

"The absence of sulphureted hydrogen in samples of unfiltered effluents which have been kept in stoppered bottles for three weeks is also a fact of importance.

"The settled sewage was not in this condition, as it rapidly underwent decomposition in two or three days, even when in contact with air.

"By this process the soluble organic matter is reduced to a condition favorable to the further purification by natural agencies."

SIR HENRY ROSCOE'S ANALYSES.

Percentage Reductions.

	Oxygen Required to Oxidize.	Albumenoid Ammonia.
No. 1	67·4	57·0
2	64·3	57·3
3	77·2	75·0
4	72·6	50·0
5	76·5	87·5
6	73·0	87·5

Another series of experiments carried out by Sir H. Roscoe, which I have tabulated, show an average reduction of sixty per cent., although the full treatment was not carried out.

I have also other lists of analysis by Dr. Meymott Tidy and Mr. Midwinter which show equally favorable results.

I have also tabulated analyses of my own carried out in 1886, showing the electrolytic action on contaminated canal water.

Here are analyses of samples taken from each section of the shoot, there being six in series. The organic matter is seen to be gradually reduced by the electro-chemical action.

I have never seen an effluent, treated in the way described, show any signs of secondary decomposition nor develop sulphureted hydrogen.

In cases where specially prepared or suitable land of a porous nature is procurable, the effluent might be wholly or partially used for manuring crops, in which case the sewage should be only so far treated that the prevention of putrefaction is assured.

The advantage of iron in the soil is one which, I think, every practical man must acknowledge. I had some sludge (deposit after electric treatment) pressed without the addition of lime, and it was applied to vegetables, the result being that a marked difference in favor of iron manure was shown in the crops when compared to others grown with ordinary farm yard manure.

The question of sludge disposal is a difficult one, and as my paper is essentially electrical, I will only mention that I should, where practicable, puddle it with chalk, and run on to waste lands, through wooden conduits, similar to the process of mixing clay and chalk in a washing mill, and running into backs, as carried out in cement manufacture, the only alternatives being filter pressing or shipping out to sea.

The bacteria question is one which has probably still to be settled; but being anxious to have some information as to the action of the iron compound produced by electro-chemical decomposition, I had some experiments carried out, with the result that after a given treatment the whole of the bacteria were killed. In the case of experiments carried out in Paris, with ordinary treatment by means of iron electrodes, the results were as follows:

	Raw Sewage.	Effluent.
Organisms per cubic centimeter.	5,000,000	600

Another experiment in which the effluent was treated still further, so that a slight odor of oxide of chlorine was perceptible, destroyed all organisms, and the liquid remained sterile.

In conclusion, I submit that the application of the electric current in the several ways I have endeavored to describe produces a precipitating and oxidizing action similar to natural processes, in which the organic matter is destroyed by oxidation due to dissolved oxygen slowly absorbed from the air, assisted in many cases by matters in the soil, such as oxides of iron, acting as carriers of oxygen, and I also consider that the question of cost will bear favorable comparison with any process which really does the work attributed to it.

THE SANITARY CONGRESS, ENGLAND.

THIS institute resumed its deliberations in congress at Worcester, on September 26, at the Guildhall, the president, Mr. G. W. Hastings, M.P., in the chair.

The prophylaxis of disease.—Sir Douglas Galton, K.C.B., D.C.L., LL.D., F.R.S., in presence of a large audience, delivered an address on the subject of certain groups of disease which were amenable to the control of preventive measures. These diseases were small-pox, typhus, enteric fever, scarlatina, measles, whooping cough, diphtheria, cholera, and phthisis.

They were now able to point with unerring certainty to the fact that given certain conditions of impure air, impure water, and a soil saturated with filth, sickness and death from one or other of these preventable diseases would ensue.

Commencing with small-pox, the lecturer said that, through vaccination and revaccination, that disease had been almost entirely obliterated in the German army, and largely in German cities. But in England we have not been so careful in enforcing either vaccination or revaccination, and we have suffered, even in recent years, from severe small-pox epidemics.

Typhus fever, which was a common and very fatal disease at the beginning of the century, was essentially associated with overcrowding and destitution. It used to be the inhabitant of our jails, under the name of "jail fever," which was of so infectious a character that on more than one occasion the judge, the jury, and the bar caught the fever from the prisoners in the court.

Typhus was essentially the disease of the pauper and badly housed elements of the community, but wherever it prevailed it might be caught by those around who were within the sphere of its influence.

Scarlatina had no such relation to water supply and drainage as had those other preventable diseases of which enteric fever is a type.

Recent investigations appeared to make it certain that the cow suffered from a disease of the nature of scarlatina, which was in some way very communicable to man through the milk. Hence the necessity of enforcing in our houses and farm yards sanitary conditions of cleanliness and pure air.

The laws governing the spread of cholera were well understood by sanitarians. Figures showed that these zymotic diseases, which Dr. Farr has aptly called "filth diseases," had of late years been largely reduced by sanitary means. Sanitation necessarily meant the increased well-being of the people, and especially of the lower class.

Epidemics could only be prevented by making the whole population sanitary, and the speaker proceeded to give some valuable advice on the subject of the conservation of the general health, concluding by producing a number of statistics showing the meaning of the preventable cause of death.

Chemistry, meteorology, and geology.—Dr. J. W. Tripe opened this section with an address, taking for his special subject winds, with remarks on their sanitary effects. He commenced by minutely describing the constituents of the atmosphere, and considered the direction of the wind in relation to its effect on the general health.

Easterly winds in this country were very trying, even to healthy persons, and often fatal to the young and old, causing more deaths in London when combined with fog, in one week, than the most violent blizzard.

He accounted for certain outbreaks of infectious diseases by winds blowing in the direction affected. Some physicians, he said, doubted the possibility of small-pox infection being carried more than a few feet; but he could not understand how, if a disease be set up by a living organism, falling on a soil in which it would develop, it should be able to infect a person at 20 feet distance, and not at 100 feet or even at half a mile.

Surely a living organism could not be destroyed (oxidized) in its passage through the air for half a mile when the wind was traveling at the rate of only four miles an hour; and yet articles of infected clothing and scabs of small-pox they knew would retain infective power for months.

The proceedings of the congress came to a close on September 28, when Prof. W. H. Corfield, M.A., M.D. Oxon., F.R.C.P., addressed a workingmen's meeting at the Worcester Public Hall on "The Mistakes Made in Life and the Remedies for Those Mistakes."

In infancy parents should, above all, not make the mistake of letting their children be too thinly clad, nor commit the common mistake of supplying infants with improper food. The only proper food for children was that which nature provided—the mother's milk. Boiled bread, tea, and starchy foods should be especially avoided in the case of infants until their salivary powers had developed.

The diarrhœa of infancy generally arose from improper feeding and rickets, called by foreigners the "English disease."

One of the greatest mistakes, again, in the treatment of children was not to have them vaccinated before they were three years old. As to their exposure to cold, it was a monstrous mistake for parents to send out their children with bare necks, heads, and legs. Children ought to be clothed from head to foot winter and summer. Children required plenty of sleep, plenty of food, together with variety either in work or play. It was, however, necessary that children should go to bed early. The worst of all habits to acquire in youth was that of drinking alcoholic spirits at any time except at meals, and of drinking "nips."

On the subject of teetotalism he would not trench. Under no circumstances should tobacco smoking be encouraged in youth. At manhood, the time of marrying and giving in marriage, he cautioned his hearers against intermarrying with members of families in which nervous or consumptive diseases were hereditary, as those diseases would be certain to recur in the offspring. At the middle age the most common mistake was overfeeding, and in old age the wearing of scanty clothing, leading to bronchitis.—*Lancet.*

SHAKEN MILK.

By JOHN C. MORGAN, M.D., Philadelphia, Pa.

EVERYWHERE this dietetic paradox confronts the physician, viz., that milk—cow's milk—is the best possible representative food; that it "contains every element of nutrition," hence, that it is *the* typical diet for the sick of all ages, as well as for the healthy; this on the one hand, and on the other, that there are few articles from which worse results may accrue to individuals, young and old.

"Starving on cow's milk" is a common phrase; and "milk is bilious," or "constipating," or causes diarrhea, or headache, indigestion, etc.; and these often parry our thrusts at malnutrition. "Acidity of cow's milk," the massiveness of its curd contrasted with human milk, with its fine flaky curd, evidencing faulty digestive processes; its deficiency in oil and sugar—all these are quoted endlessly, to explain the paradox, and doubtless all are significant; but there are other important considerations which are less considered, and these are, in my judgment, largely as follows:

First, human milk, drawn by the child, is a nascent life product. Cow's milk at its first emission is equally so. Secondly, both are living fluids, and their contained cells are the site of vital metabolisms, all, doubtless, promotive of assimilation and of digestion itself. Thirdly, their oil globules and casein granules are sundered and enveloped by their containing shells of albumen and the watery menstruum.

Milk which has died, whether human or cow's milk, has ceased to be nascent, has ceased its living metabolic cell mutations, has become a mere physical or mechanical admixture of bodies of unequal density and specific gravity, whose particles separately mass themselves, and within a few hours, if undisturbed, form crude strata, as cream, heavy caseous milk, and whey; each, after long intervals, becoming very distinct, as is proved by the so-called "candles" formed in the large test tubes in use in condensed milk factories. Preservation on ice does but promote this change. Sterilizing processes, *per contra*, interfere with it, over and above the intended germ destruction, inasmuch as the high heat, with agitation, prevents rapid separation. The housewife recognizes the same principles when preparing "curds and whey," or "slip," with milk and the pepsine-bearing rennet, choosing a cold and quiet place for the setting of her pan, her object being to obtain a half-digested, massive, unruptured curd, with its transparent substratum of watery albumino-saline fluid, or whey. Most stomachs can easily complete the digestive process thus begun—for it is nothing else—and it rarely disagrees with any one. Should it do so, we may, by beating or shaking it, break up the curdy mass (with the aid of an admixture of atmospheric air), thus reducing it to the finely comminuted flaky state so admired in "mother's milk," and intimately mingling it with the whey at our option. Afterward, the process of curdling being complete, these particles have but feeble tendency to reunite; are, indeed, until decay sets in, in excellent condition for the full play of the digestive organs.

Cow's milk, as received from the milkmen, especially in hot weather, has undergone an incipient change of like nature. Chilled and quiescent during the night, the evening's milk is combined with that of the early morning, but both are carefully deprived of all remaining "animal heat." The whole becomes as one by this treatment. The motion of carriage opposes, but the tendency to mechanical separation has already fairly set in. Received now at our dwellings, and transferred to the refrigerator, this separation goes on rapidly, and indigestibility progresses *pari passu*.

To counteract this change, so far as may be, would seem to be the dictate not only of science, but as well of common sense. To prevent the gastric struggle with curdy masses, one need but insure the comminution of those masses, and thus invoke mutually repellent forces of the minute particles of oil, water, and casein. The rapid digestion of each and all of these in gastric and pancreatic juices should now occur without the aid, ordinarily, of pepsin or pancreatin artificially introduced.

Such is the theory I would propound, and I have witnessed a number of cases of its practical and successful application. One of these is a stout florid gentleman, of about sixty years, who is subject to the usual disturbances from drinking even the best quality of milk. The preparation now so popular under the name of "milk shake," at an extremely low temperature, too, agrees with him perfectly, and is readily and speedily digested. Another case is that of a physician, fifty-two years of age, convalescent from malarial fever, for whom I prescribed a milk diet; but who met me with the fatiguing statement that it is always disastrous to him. Lime water did not better the matter. I now advised that it be violently agitated by shaking or beating, with a view to comminution of its massive elements—the oil and the casein—and their thorough diffusion in the whole of the fluid portion; this preparation to be taken in small portions until the teacupful was finished. This was duly accomplished by means of a conical tin cup, such as is used by bar tenders, being closely fitted over the top of a glass of milk, and the whole vigorously shaken for some time just before drinking (in sips, as directed). The result was really charming. His own report was: "Here is a man who never has dared, in many years, to drink a glass of milk, but who now takes it, in the new way, every day, and is building up on it."

The use of milk just drawn from the cow is also important for infants and weakly persons; but most people can do admirably well, I opine, on "shaken milk."

Judging from my own experience, I think it is not too much to predict that in the future the medical and other attendants in typhoid cases, perhaps in infantile disorders and in many others in which patients refuse everything in the way of "sick diet," and crave everything which they must be denied—particularly as to those who "cannot take milk"—will find the solution of the perplexing but essential problem in providing, as an indispensable utensil, the bar room tin, and regularly using it, in the preparation of shaken milk.

A dilution of milk with one-tenth of water "scalded," not boiled, and taken hot, or even ordinary hot milk, is a noble stimulant (*versus* alcohol) in threatened collapse, and in debility in general. If shaken, also, it must prove invaluable in a wide range of low cases.

When a cold drink is more suitable, as in some febrile conditions, cracked ice may be added to milk before shaking; and lastly, when the taste is fastidious, strawberry or other fruit sirup, or any other approved ingredient, may also be introduced.—*Med. Record.*

THE STRENGTH OF ALLOYS AT DIFFERENT TEMPERATURES.*

By Professor W. C. UNWIN, F.R.S.

THE strength of the commonly used alloys, such as gun metal and brass, at moderately high temperatures, is a question of some practical importance. It is well known that iron and copper decrease in tenacity as the temperature is raised, the latter in a very marked degree. There are also experiments showing a still more considerable decrease of tenacity in gun metal. The author's attention was directed to the matter in studying some experiments made for the Admiralty in 1877. In these experiments, copper, Muntz metal, and phosphor bronze showed a tolerably regular decrease of tenacity, as the temperature was raised to 500 deg. Fah. But in the case of gun metal the results were more anomalous. The gun metals tried were all alloys of copper, tin, and zinc. In the bars tried the tenacity diminished tolerably regularly up to a temperature of 300 deg. or 350. But beyond that temperature there was a sudden decrease of tenacity, generally, of more than 50 per cent., and at a temperature of 500 deg. in several cases the tenacity had become *nil*. Now at the high pressures, and correspondingly high temperatures, at which steam engines are often worked, gun metal is exposed in many cases to temperatures of 350 deg. or 400 deg. It is practically important to know if at such temperatures its strength is seriously impaired. At any rate, the author found that there were but few experiments on the strength of alloys at different temperatures, and of some of these the trustworthiness was doubtful. Hence it appeared that it might be useful to make some new experiments.

In the present experiments the bars to be tested were fixed in an oil bath, heated by a gas jet. The middle part of the bar for a length of 2 in. was turned down to a diameter of ¼ in. or $\frac{5}{16}$ in. The temperatures were taken by a mercurial thermometer. It is believed that the temperatures are quite accurate, except those

* British Association, Section G.

above 600 deg. Above 600 deg. the thermometer behaved irregularly. The bars were broken in a small special testing machine of the manometer type, the pressure on the diaphragm being balanced by a mercury column.

Rolled bars of yellow brass, Muntz metal, and Delta metal were tried, and the results on these are quite regular. Some bars of cast brass also gave very fairly regular results. The bars of gun metal gave results of less regularity. This is due, in part at all events, to the fact that some of the bars cast first proved unsound, and new bars had to be cast to replace them. At some future time the author hopes to try a series of gun metal bars all cast at the same time. The results were plotted in a diagram, and show that in all cases the decrease of strength follows a regular law, without any such sudden loss of strength as was shown in the Admiralty experiments. Even at temperatures of 600 deg. to 650 deg. all the bars had still a not inconsiderable tenacity.

The ultimate elongation of the bars in the 2 in. test length was measured, and is given in the table. There is a peculiarity in the influence of temperature on the ductility of the bars. In most cases the ultimate elongation diminishes with increase of temperature. With Muntz metal that decrease is regular, and there is still considerable elongation before fracture at a temperature of 650 deg. With yellow brass—rolled—the decrease is more rapid, and there is very little elongation before the fracture at temperatures above 500 deg. Cast brass behaves in the same way. The elongations of the gun metal bars were very irregular, and at temperatures of 600 deg. and upward the elongation was extremely small. On the other hand, in the case of the Delta metal bars the elongation increased regularly with increase of temperature. The contraction of area was also measured. This follows generally the same law as the elongation at fracture, but the contractions of area are more irregular than the elongations.

Testing of Metals at different Temperatures.

Laboratory No.	Diameter in ins.	Section in sq. in.	Temperature Fah.	Tenacity in tons per sq. in.	Elongation in 2in. per cent.	Contraction of section per cent.
			Yellow Brass.			
938	·308	·07451	atmospheric	24·09	41·0	61·0
941	·309	·07499	235°	22·44	30·5	23·0
939	·307	·07402	406°	21·23	19·0	10·0
940	·312	·07645	5·0°	18·33	5·0	very little
942	·308	·07402	602°	15·86	2·5	" "
943	·309	·07499	640°	14·49	1·0	" "
			Delta Metal (Rolled).			
945	·249	·04870	atmospheric	31·16	20·0	55·0
949	·243	·04638	20·°	28·30	22·0	47·0
946	·249	·04870	400°	26·58	25·0	53·0
944	·249	·04870	500°	23·83	27·9	59·0
947	·245	·04714	570°	19·32	38·5	60·0
948	·240	·04524	650° abt.	16·04	33·0	48·0
			Muntz Metal.			
950	·302	·07163	atmospheric	24·68	35·0	59·6
951	·309	·07499	300°	22·83	28·5	41·2
952	·310	·07548	400°	20·84	37·5	55·1
953	·311	·07596	500°	18·81	28·5	38·4
954	·306	·07354	608°	16·69	17·0	19·2
955	·310	·07548	650°	17·15	16·0	very little
			Gun-metal.			
977	·376	·11104	210°	11·66	10·0	16·8
980	·376	·11104	380°	12·26	17·0	18·2
979	·376	·11104	406°	11·06	12·5	12·8
957	·309	·07499	440°	12·30	16·5	7·6
981	·376	·11104	500°	7·84	13·0	14·8
978	·376	·11104	600°	5·22	1·5	2·1
982	·376	·11104	600°	7·84	—	very little
960	·311	·07596	615°	4·82	—	" "
			Cast Brass.			
989	·376	·11104	atmospheric	12·45	24·0	16·4
991	·376	·11104	350°	11·83	27·5	23·4
992	·376	·11104	450°	10·40	23·0	22·5
990	·375	·11045	500°	7·69	11·5	16·2
993	·376	·11104	550°	7·68	13·5	17·8
994	·376	·11104	645°	3·23	—	very little
			Phosphor Bronze (Cast.)			
995	·312	·07645	atmospheric	16·06	13·5	10·0
1000	·312	·07645	270°	14·16	12·5	12·4
997	·312	·07645	350°	12·26	7·5	10·0
999	·312	·07645	430°	12·41	10·5	8·7
996	·312	·07645	500°	11·10	6·0	6·8
998	·312	·07645	600°	8·17	3·5	2·5

PLATINUM.

CHARLES WOOD, an assayer, in 1741 found in Jamaica some platina which had been brought from Carthagena and which he forwarded to London for inspection as a curiosity.

The first to mention platina by its present name, however, which means "little silver," was Don Antonio Ulloa, a Spanish mathematician, who, in 1736, accompanied the French academicians who were sent to Peru by their sovereign to measure a degree of the meridian in order to determine the figure of the earth.

After his return he published at Madrid, in 1748, a history of his voyage, and mentioned the abandonment of the gold mines in the territory of Choco on account of the presence of platina, which, being too hard to easily break or calcinate, the gold could not be extracted without much expense and great difficulty.

It is reported in the *Chemical Annals* for July, 1792, that the miners of Choco, discovering platina was a metal, began to use it in adulterating gold, in consequence of which, the court of Spain, fearing disastrous results therefrom, attempted not only to prevent its export, but to conceal the discovery of the metal from the world.

To effect this, all gold brought from Choco to be coined at the two mints of Santa Fe was carefully inspected, and all platina separated and given to the king's specially appointed officers, and when a sufficient quantity had accumulated, it was taken to the river Bogota, about two leagues from Santa Fe, or to the river Cauca, about one league from Papayan, and, in the presence of witnesses, thrown into the rivers.

From the great specific gravity of this metal, it being the heaviest known, together with its malleability and ductility, and the fact of its great resistance to the action of acids, alkalies, and sulphurs, it has become known as the "metal of the chemists."

Some of the most important discoveries of modern chemistry would have been impossible without the aid of platina. It is so soft it may be readily cut with the scissors, and when formed into a mirror, reflects but one image.

Platina has been found in various parts of the world, Peru, New Granada, Brazil, St. Domingo, and in the gold washings of California, Australia, and Borneo, but the principal source of supply is in the Ural Mountains of Russia and the auriferous sand of Kuschwa, in the Auralian Mountains of Siberia.

Platina is rarely found in pieces larger than a few grains in weight.

The chief uses of platina are for the various apparatus used in chemical laboratories, such as crucibles (first crucible was produced in 1784), spoons, blow-pipe points, tongs, forceps, and boilers or stills for concentrating sulphuric acid. A still of this kind, valued at 95,000 francs, was exhibited at Vienna in 1873, capacity 20,000 pounds of sulphuric acid daily.

An ingot valued at $20,000 was exhibited at the London exhibition of 1862.

On account of the high degree of heat requisite to fuse or melt platina—melting point 1,460° to 1,480°—it is the only metal used for making the pins of porcelain teeth, and on account of its value and lack of any known substitute, has become the greatest item of expense in their manufacture.

It is also utilized for making fine jewelry, and a great and growing demand has been but recently created by the development of electricity.

The Russian government began coining platina for general circulation in 1826 and continued until 1845, when, by an imperial ukase, the coinage was discontinued and the $2,500,000 issued called in because of the great fluctuation in the price of the metal.

The average production of platina metal from 1828 to 1845 amounted to 2,623·8 kilos or 5,784·48 lb. per annum; from 1875 to 1884 inclusive, the average yield of the Russian mines was 3,483·3 lb. per annum, showing a decrease since 1882, the maximum year, of 45 per cent. in the yield. The Rusian mines yield 80 per cent. of the total product of the world.

The price of platina, which has always ruled very high in consequence of the continually increasing demand, the limited source of supply, without any new discoveries of moment, sufficient to relieve the market, is constantly advancing—so rapidly, indeed, as to cause serious apprehensions for the future.

Those industries whose manufactures depend largely on platina as their chief element of cost (and with no known substitute in sight), such as stills, crucibles, porcelain teeth, electrical and mechanical apparatus, etc., are suffering more or less seriously from this increase in price, and for self-protection, it would seem, will be obliged to advance prices proportionately.—*Electrical Review.*

A JOURNEY TO THE HEAD WATERS OF THE ORINOCO.

UNDER this title *La Ilustracion* of Barcelona is publishing a series of interesting articles by Juan Chaffanjon, giving an account of his adventures in the almost unknown upper regions of the great Orinoco River, South America. At one time he came upon a great boa constrictor, coiled up and asleep, of which he took a photograph, the first probably ever taken of this reptile in its native lair. At another time he surprised a camp of the savage Guaharibos Indians, and of their curious huts he gives a photograph which we reproduce. The huts are rude shelters of leafy canes tied at the top; they are arranged in a circle around a central fire, and the Indians squat under their huts as shown, thus making themselves very comfortable.

A BOA CONSTRICTOR.

HUTS OF THE GUAHARIBOS.

DARWINISM.

UNDER this title Dr. Alfred R. Wallace, the well known naturalist, has brought out a new work, of which a review is given by Prof. E. Ray Lankester in a recent number of *Nature*. Prof. L. says:

The object of Mr. Wallace in writing the admirable work which he has published with the title of "Darwinism" has been "to give such an account of the theory of natural selection as may enable any intelligent reader to obtain a clear conception of Darwin's work, and to understand something of the power and range of his great principle." No one has so strong a claim as Mr. Wallace to be heard as an exponent of the theory of the origin of species, of which he is, with Darwin, the joint author. He has produced a thoroughly readable book, condensing into an octavo volume much of the speculation and description of important facts which are contained in the numerous volumes published by Darwin himself and in the essays and occasional contributions of subsequent writers. Besides this, Mr. Wallace's book contains an exposition of highly important and interesting views of his own on subsidiary matters, which have either not been published previously or have appeared in a scattered and more or less inaccessible form. Consequently, the book is one which has interest not only for the general reader, to whom it is primarily addressed, but also for the more special student of natural history. The latter will find in its pages an abun-

dance of new facts and arguments which, whether they prove convincing or not, are of extreme value and full of interest. The reviewer then points out some of the shortcomings of Mr. Wallace's treatise, not, he says, from any desire to minimize its value and interest, but rather in acknowledgment of the weight and significance of a work on so important a subject by so specially competent an author.

Prof. L. in closing remarks: Of the American evolutionists Mr. Wallace justly says: "In place of the well established and admitted laws to which Mr. Darwin appeals, they have introduced theoretical conceptions which have not yet been tested by experiments or facts, as well as metaphysical conceptions which are incapable of proof." They have, in fact, conspicuously abandoned the "scientific method."

The words which Mr. Wallace has applied to the American evolutionist are, in the opinion of many, strangely applicable to portions of his own concluding chapter on "Darwinism applied to Man." He here introduces us to a spiritual world, and to different degrees of spiritual influx. Mr. Wallace is in the peculiar position of one who believes that he has experimental evidence of the remarkable theoretical and metaphysical conceptions which he introduces. He boldly takes up this position, and we may be sure that he would not wish attention to be diverted from it. It remains an interesting problem for the future student of human faculty to reconcile Mr. Wallace's wonderful ingenuity and skill as a reasoner and observer concerning animal life with his views as to the so-called "manifestations" of spiritualists.

Mr. Wallace's contention that the mathematical, musical, and artistic faculties of man have not been developed under the law of natural selection must in large part be conceded. While the earlier development of these faculties may be explained as due to natural selection, since some amount of each may well have been an advantage to the primitive man in his struggle for existence, it is yet true that their sudden and rapid development to a very much higher level in civilized communities cannot be traced to the struggle between man and man. It does not, however, follow that because natural selection will not account for these extraordinary developments of the human brain, therefore we must have recourse to the assumption of supernatural agencies. Mr. Wallace seems so much convinced of the importance and capability of the principle of natural selection that when it breaks down as an explanation, he loses faith in all natural cause, and has recourse to metaphysical assumption. On the other hand, it must be contended that we know very little of the development, either in the individual or in various races, of these and other faculties of the mind.

[Continued from SUPPLEMENT, No. 724, page 11572.]

METEORITES AND WHAT THEY TEACH US.

II.

By H. HENSOLDT, Ph.D., Assistant in Natural History, School of Mines, Columbia College, New York.

FORTUNATELY it is an easy matter to distinguish meteoric iron from iron which has been artificially produced, no matter when or by whom. If we file or grind a piece of meteoric iron so as to produce a smooth, or better still a polished surface, and apply to this a few drops of diluted hydrochloric, sulphuric, or nitric acid, we shall see it covered, as if by magic, with extraordinary parallel lines, rods, or bars, intersected by others under certain definite angles. They are exhibited almost invariably by the iron of meteorites, and are known as Widmanstattian lines, from their first discoverer. They are due to a crystalline structure of iron and to the fact of its being nearly always alloyed with a small quantity of nickel (also a trace of cobalt and copper).

Crystallization, as pointed out by Dr. Huntington,* in some respects may be looked upon as a purifying process. When a mineral crystallizes it invariably endeavors to rid itself of foreign particles, which are generally present, by driving them to the periphery, where they form a zone or layer. If the crystallization is then interrupted and resumed again at a later period, the expelled matter will form a zone in the crystal, often of extreme regularity, and this process may be repeated a dozen times, so that in the sections of many crystals we find a series of zones of such foreign particles, each representing the outline of the crystal at a certain period of its development.

Now during the solidification of the meteoric iron there was an effort, as it were, on the part of the pure iron to rid itself of the nickel by driving it in successive layers to the margin; thus we have in the meteoric iron bars of almost pure iron, the so-called Balkeneisen or kamacite alternating with narrow seams of iron rich in nickel, the taenite or bandeisen.

The Widmanstattian lines were already discovered in 1808, and as early as 1816 Sommering recorded his opinion, as the result of careful angle measurements, that they were due to an octahedral crystallization. Now in 1848, another set of lines was discovered in certain meteoric irons by Neumann, especially in the iron which fell at Braunau, in Bohemia, in 1847.

These lines, which are quite different from those above described, were found to denote a cubical crystallization, and they have since been known as Neumann lines.

They intersect each other at right angles, parallel to the faces of a cube, and sometimes are traversed by diagonal lines, indicating a twinning of the cube.

The Widmanstattian and Neumann lines have hitherto served as a basis for dividing the iron meteorites into octahedral and cubic irons.

Dr. Oliver W. Huntington, however, has successfully shown that such a classification is neither natural nor fundamental, and that the Widmanstattian figures and Neumann lines are sections of planes of crystalline growth parallel to the three fundamental forms of the isometric system, namely, the octahedron, the cube, and the dodecahedron.

Analysis has revealed that the cubic irons are purer (less alloyed with nickel, etc.) than the octahedral ones, and Tschermak especially draws attention to the fact that in the case of artificial irons the pure iron tends toward a cubic crystallization with markings like the Braunau meteorite. This can be strikingly observed in the so-called spiegeleisen, a variety of cast iron.

The element of time is of primary importance in determining the crystalline structure of the iron, as during a very slow process there would be a more complete elimination of foreign materials than during a rapid solidification.

The action of the process of crstallization in eliminating impurities produces effects with many minerals not unlike those of the Widmanstattian figures, as we may see in rock sections containing leucite, nosean, nepheline, etc.*

That excellent observer, Dr. Huntington, also draws attention to the mica from Chandler's Hollow, Del., in which particles of magnetic oxide of iron are deposited in lines, which are also sections of planes of crystalline growth. Plates of this mica present, in the configuration of their lines, a close analogy to the etched surfaces of octahedral meteoric irons.

Prof. Sorby, in an article published in *Nature* in 1877 (vol. xv., p. 498) writes: "These facts clearly indicate that the Widmanstatt's figuring is the result of such a complete separation of the constituents, and perfect crystallization, as can only occur when the process takes place slowly and gradually.

"They appear to me to show that meteoric iron was kept for a long time at a heat just below the point of fusion, and that we should be by no means justified in concluding that it was not previously melted.

"Similar principles are applicable in the case of the iron masses found in Disco; and it by no means follows that they are meteoric because they show the Widmanstatt's figuring."

Now these Greenland iron masses were discovered by Nordenskjold in August, 1870. It had been known for a long time that the Esquimaux were in possession of knives and hatchets which they had themselves made from iron, which seemed to be meteoric, as it exhibited the Widmanstattian lines. These implements were found in such abundance among the inhabitants of the southwestern coast of Greenland as to induce the belief that their supply of the raw material must be very considerable, but nothing could induce the natives to reveal the locality. In 1870 Nordenskjold succeeded in clearing up the mystery, and from information which he obtained at Upernavik he procured guides and proceeded to the island of Disco, a little to the south, under lat. 69° 19', where he found what he believed to be the largest meteorite ever discovered. It was an iron mass about six feet long and nearly as broad, weighing no less than 42,000 pounds. Within a few yards from it lay another, weighing 16,000 pounds, and four or five more of lesser weight, but the entire sea shore was also strewn with iron pebbles, varying from the size of a sand grain to that of a cocoanut. Most of the larger masses presented the usual features of meteoric irons, in their outward appearance as well as their chemical constitution, for it was found that they consisted of iron alloyed with nickel and cobalt. Small wonder therefore that Nordenskjold and even Tschermak for a long time persistently adhered to the opinion that they were of cosmic origin. But a careful examination of the locality by Steenstrup, who visited Disco in the spring of the following year (1871), revealed the startling fact that these irons are, without exception, terrestrial, and have been weathered out of a huge bed of basalt, which contains metallic iron in abundance.

Steenstrup found that at Disco, within a few hundred yards from the shore, the cliffs rise to a height of 2,000 feet above the sea level. A basalt breccia of dark green color, and about 200 feet in thickness, rests on an ancient fundamental gneiss. Above the breccia lies a bed of vesicular basalt wacke, the cavities containing cabasite, mesotype, analcime, and other zeolites, and this again is covered by a basalt sheet of enormous thickness, sometimes attaining one thousand feet, composed mainly of anorthite, augite, and *native iron*, the latter often in nodules of considerable size. This immense basalt stratum, produced by volcanic outbursts on the grandest scale during the Miocene period, can be followed along the entire western coast of Greenland, extending far beyond Smith's Sound, over ten degrees of latitude, until it finally disappears under a huge glacier. We shall probably never know *how* far this gigantic lava stream, with its incalculable wealth of nickeliferous iron, stretches to the frozen north.

About ten years ago the writer, when examining a number of thin sections prepared from the meteorite of Braunfels, which was found in Germany in 1878, made a discovery, which, however, he did not follow up in its important bearings, on the origin of these cosmical bodies, as the meteoric character of the Braunfels specimen was not clearly established. Tschermak and Brezina, for instance, declared the meteorite of Braunfels to be a pseudo-meteorite, on the ground that it differed so much in its structural features from every other known meteorite as to render its extra-terrestrial origin very doubtful. But quite recently the writer has made the same discovery in the meteorite of Loutalaks, a well authenticated meteorite, which fell in Finland in 1813, and also in that of Nobleborough, Lincoln county, Maine, as well as in that of Bustee, which fell in India in 1852. These meteorites are of a brecciated character and belong to a class which has been called howardites by Gustav Rose. They consist of angular fragments of anorthite, pyroxene, etc., with little or no metallic iron.

Now the writer's discovery does not, like that of Dr. Otto Hahn, relate to organic remains; if it did, it is doubtful whether he would have the courage to communicate it to the world after Hahn's ludicrous fiasco. He has simply discovered fluid inclosures in the sections of at least three meteorites, minute cavities, filled with a liquid such as we find in abundance in terrestrial rocks. This may seem a very trifling matter, but we shall soon see that its significance is very great.

There is nothing more common in terrestrial minerals than little inclosures of fluid. If we prepare a thin section from one of the whitish quartz pebbles to be found in every river bed or gravel deposit and examine it under the microscope with a low magnification, we observe the whole field crowded with minute dust-like particles like a sort of cloud. Now if we increase the magnification, these dots will enlarge in proportion to the power employed till each expands into a well defined cell or cavity, in the interior of which a round object is seen constantly moving about. These cell-like objects are cavities filled with a liquid, and the moving body in each is a bubble which is perpetually altering its position. In the largest of the cavities the motion is barely perceptible, but in the smaller ones it is quite lively, the bubbles darting rapidly from one side of the cell wall to the other. Now what causes the white appearance of the so-called milky quartz? Some coloring principle, one would naturally conclude. Nothing of the kind; the white color is entirely owing to the presence of countless millions of fluid inclosures. The cavities do not imprison a white liquid; the white color is merely an optical phenomenon due to the reflection of the light by the myriad walls of the cavities. We have exactly the same thing in snow, which is not white by virtue of a color; if we melt it, we get the clear water of which it is composed.

Before we return to our meteorites a few observations on the cause of this perpetual motion may not be out of place. This bubble movement has nothing to do with "Brownian" motion. In the latter we have minute solid particles driven about by molecular currents in a liquid. If, for instance, we dissolve a little Indian ink or gamboge in water and examine a drop of this under a "quarter" or "sixth" objective, we are startled to behold a very lively motion of the minute particles, a motion which never ceases till the drop has evaporated, and if we were to inclose it in an air tight cell, it would continue for years, or centuries for that matter. This is Brownian motion. But the bubble movement in our fluid cavities is due to the ever-varying temperature of the atmosphere. The temperature of the air which surrounds us is never constant, although we cannot with our coarse instruments perceive very small differences. We only see the rise and fall of our thermometers after changes more or less considerable, but in reality there is a perpetual change of level in the quicksilver column. If we were to focus a high power objective on the marginal level of that column, we should see it constantly shifting and never observe it at rest. The same effect can be shown with a delicate spirit level. If a spirit level be placed on a table and so adjusted that the bubble is in the center, the holding of one's hand in the air within a foot's distance from the end of the tube suffices to cause a disturbance. The warmth of the hand drives the bubble slowly from its position, which it will resume when the equilibrium is restored.

The liquid imprisoned in the cavities of quartz and other minerals is generally water. Sometimes this water is strongly charged with chloride of sodium, and in the cavities of many granites (notably in those of Cornwall) we frequently observe cubic salt crystals floating about in the liquid. This would indicate a saturated solution which once doubtless filled the entire cavity, but in the course of ages some of the water either evaporated through the rock or a considerable lowering of temperature took place, so that a corresponding quantity of the salt was precipitated. Occasionally the liquids are hydrocarbons, oily, petroleum-like substances.

About twenty years ago Vogelsang and Geissler made the singular discovery that in many rocks the imprisoned fluid consists of carbon dioxide, liquefied carbonic acid, and from experiments which the writer has made, he has come to the conclusion that the fluid contained in the cavities of the meteorities of Loutolaks, Noblesborough, and Bustee is likewise CO_2. On warming the meteoric sections by means of a wire coiled round the slide and observing the temperature on a stage thermometer, the writer invariably found that the bubbles suddenly vanished when a temperature of about 30° C. was reached, but returned again in cooling without any apparent diminution in size or moving capacity. Now between 30° and 31° C. lies the so-called "critical point" of carbonic acid, that is, above this temperature carbonic acid cannot exist in its liquid condition, however great the pressure may be to which it is exposed. This is in accordance with an interesting law, the existence of which has been proved beyond any doubt by recent investigation. After certain temperatures are reached, liquids enter into the gaseous state, no matter what the pressure may be. The temperature under which a certain liquid is no longer able to retain its characteristic features, but transforms itself into a gas, has been called by Prof. Andrews, of Belfast, its "critical point," and from experiments made by him it has been convincingly shown that it is not possible to maintain the liquid condition of CO_2 at any temperature beyond 30° 92' C. In all the cavities contained in these meteoric sections which have come under the writer's observation the bubbles suddenly vanished at a temperature of from 30° to 31° C., sometimes even exhibiting that peculiar phenomenon of ebullition to which Mr. Noel Hartley, more than ten years ago, already drew attention. Now if the inclosed fluids had been water, the bubbles would not have shown the least indication of a change at this temperature. The writer heated a section of quartz, the cavities in which he knew to contain water, to the boiling point without detecting the smallest effect on the bubbles.

Among the many chemical tests which have been resorted to in order to determine the presence of carbonic acid in mineral cavities we will only mention that of Vogelsang and Geissler, of Bonn, who crushed rock crystals in which cavities occurred which they suspected to contain liquefied CO_2, under baryta water, and observed that the latter became turbid, owing to the formation of carbonate of baryta.

Now, taking for granted that the fluid material contained in the cavities of these meteorites is really carbonic acid, which we may safely do, as it presents no points of analogy to any other known substance, and that the bubbles which move so restlessly about in their tiny prisons are the same substance in its gaseous condition, what do these facts teach us respecting the circumstances under which the meteoric masses were originally formed?

Carbonic acid is a gas which can only be reduced to the condition of a liquid by extreme pressure. It requires a pressure of no less than 65 atmospheres to condense CO_2, which is equivalent to a column of water 2,000 feet high or a rock stratum of about 700 feet thickness. Wherever we find inclosures of liquid carbon dioxide in terrestrial rocks—and we find them frequently—we may take it for granted that the formation of those rocks took place deep in the earth's crust

* "On the crystalline structure of iron meteorites," Proc. Am. Ac. Cambridge, 1886, p. 491.

* Vide O. W. Huntington "On the crystalline structure of iron meteorites."

under the gigantic weight of superincumbent masses. Cavities containing CO_2 often occur in basalts and other so-called "basic" lavas, which are known to be derived from deep-seated reservoirs beneath volcanoes, where, besides the weight of tremendous rock masses above, we have the compressing force of great quantities of elastic vapor held in confinement, while in the so-called acid lavas (lavas rich in silica), of which there is very conclusive evidence that they are formed at no such very great depths, the presence of liquefied CO_2 is extremely rare.

The fact that these cavities are often contained in the quartz of granites may be regarded as a most important evidence that the granites have been formed deep in the earth's crust, under conditions of enormous pressure, and we never find this liquid in sedimentary strata or any other materials which are unlikely to have been exposed to extreme pressure during their formation.

But how about *extra-terrestrial* rock masses? How about meteorites in which we find liquefied carbonic acid in millions of minute cavities? Could they have originated under circumstances totally different from those which prevail on this globe? Could the CO_2 in them have been condensed to a liquid *without* extreme pressure? Certainly not; this would be little short of a miracle, and as we cannot conceive the possibility of such a great pressure in a meteorite, weighing only a few pounds, we are driven to the conclusion that those bodies at one time of their history existed in the interior of mightier masses, planets, perhaps, of which they are the fragments.

It has, as we know, been ascertained by the means of the spectroscope that the fixed stars are for the greatest part composed of elements identical with those which prevail on this globe, and that most of the planets that are within our observation are composed of materials very similar to those which constitute the earth, we have strong grounds for believing. Then we know that the sun's temperature is so enormous that all the non-metallic elements and many of the metallic are in a condition of vapor and the rest of the metals in a state of fiery liquid, and probably all the fixed stars are similar masses in different stages of cooling. We furthermore find traces of mighty igneous action on those planets which are nearest to our observation, for instance the moon, which is covered in many parts of its surface with volcanoes on the grandest scale (now, as it seems, extinct forever), and our own earth yet displays mighty volcanic forces which seem to have been grander still in the past.

What, therefore, can there be improbable in the supposition that among the myriads of those fiery drops or half-cooled orbs, but in whose interiors mighty volcanic elements still are busy, one should *explode* now and then and people the universe with its fragments? We have evidence to prove that in past periods of the earth's history the explosive force of vapors held in confinement has been great enough to blow away mountains ten miles in diameter, leaving chasms which are now, in many instances, filled by lakes.

On the island of Timor, for instance, an active volcano, which was visible from a distance of 300 miles at sea, was blown away during a terrific eruption, and the circular lakes of Italy, Auvergne, the Eifel, etc., mark the sites of ancient volcanoes.

The remarkable ring mounds which we observe on the moon have, in the writer's opinion, originated in the same manner, and tell a tale of explosions so stupendous and terrible that the mind can barely conceive it.

What eruptive forces have been able to achieve on this globe even a few years ago is shown by the occurrences on the island of Java, and during the still greater eruption of Papandayang in 1772, more than half the mountain was blown away; it was in one single night reduced in height from 9,000 to 5,000 feet.

That heavenly bodies, such as planets, should be capable of exploding seems not only possible but extremely probable. If in the interior of our own planet the force of vapors held in confinement had been great enough to transplant gigantic mountains and to effect the most appaling changes in the aspect of the surface, there is nothing illogical in the conclusion that vast accumulations of gases may lead to the scattering of whole worlds, or that the violence of explosion may rain them partly, hurling fragments far enough to place them beyond the attraction of the remaining wrecks.

On such stupendous explosions taking place it is almost certain that great numbers of fragments would be sent through space in similar directions, forming swarms, which, on coming within the attraction of some great body, would take definite courses, while many others would be so directed as to diverge the further they move, till each pursues a solitary path.

The magnificent showers of so-called shooting stars have been proved to be caused by the passage of the earth through such bands of traveling bodies, and even comets have now been identified with streams of planetary bodies of minute size, moving in regular orbits through our system.

Now as it is extremely probable that many meteorites are fragments of the celestial bodies vastly mightier than themselves, their closer examination leads us to the conclusion that at least *some* are derived from planets very similar to, if not identical in composition with, our globe, and that they come from the *interiors* of those masses and are the resultants of explosion.

If we examine those minerals which most frequently occur in meteorites, we are startled to observe that they are almost without exception those which constitute the basic lavas, viz., those volcanic rocks which, as we have already pointed out, are derived from the deepest seated igneous reservoirs in the crusts of our planets. Olivine, enstatite, augite, anorthite, magnetite, and chromite are most frequently contained in meteorites, and these are the very minerals of which the basic and ultra-basic lavas almost exclusively consist.

Masses bearing the most striking resemblance to meteorites are sometimes ejected from volcanic vents in the shape of so-called volcanic bombs, and even metallic iron has now been discovered in the most basic of all known terrestrial lavas, viz., the Ovifak basalt, iron alloyed even with two other metals, nickel and cobalt, which forms so characteristic a feature in the iron of meteoric origin.

We know comparatively little of the interior of our planet, being only acquainted with a very insignificant portion of its crust, and even the basic lavas, which in all probability represent the deepest known regions of that crust, furnish us with but very scanty information respecting the nature of the vastnesses beneath. But though we shall probably never be able to ascertain the condition of the interior of the earth by direct observation, we are in the position to say that the masses forming the bulk of this interior must be quite different from those which constitute the crust.

It has been established that the average density of the earth is a little over 5½—in other words, the earth weighs 5½ times as much as a globe of the same size composed of water; but that the specific gravity of the known crust, viz., the average weight of the rocks, minerals, etc., with which we are acquainted is less than 2½. We are thus driven to the conclusion that the interior of the globe is composed of substances having more than twice the density of those which we find at the surface.

Now it seems to the writer that in the meteorites which have from time to time fallen upon the earth's *surface* we have been provided with a most important collection of objects on which to study the character of its interior. Being the fragments of other planets, they confirm in a remarkable manner those general conclusions which we have been enabled to draw from undisputed facts respecting the interior of the globe. The density of by far the greatest number of them wonderfully coincides with that of the greater portion of the globe. It has often been pointed out that the interior of the earth is in all probability a vast metallic mass consisting mainly of iron, and among the meteorites we have a great preponderance of iron masses, while the different classes of meteoric, with exception of the chondrites (which beyond doubt have resulted from the accumulation of cosmic particles) represent a variety of lesser depths, those which are of an essentially stony character being delivered from portions of the crust.

It has been the writer's endeavor in the above to give a brief outline of what has been accomplished in recent years by those devoted to the study of meteorites. Much of what he has stated will be nothing new to those who may be acquainted with the existing literature on meteorites and who have kept pace with the progress of recent inquiry. But it would gratify him if his efforts have awakened more than a passing interest in others, if he should have succeeded in showing that the study of meteorites has an importance far beyond that which they have hitherto attributed to it; that it is of importance to the physicist, astronomer, and philosopher; that without it no rational conception of the constitution of this universe is possible, and that even now no progresive geologist, mineralogist, chemist, or teacher of natural history—in short no one who pretends to a scientific education—can afford to ignore it.—*The American Geologist.*

RAMIE.*

By JULES JUVENET.

I AM here to contribute my share of labor to the success of the ramie industry, which is destined to revolutionize, ere long, the textile markets of Great Britain and America, and moreover to considerably develop the production of the Southern States, as well as the manufactures of the Northern States; but, before entering upon my subject, let me request your indulgence for attempting to address you in a language not my own.

What is ramie?

It was formerly placed by the botanists in the class of *Urtica*, but it is now called *Boehmeria*, or spearless nettle.

I will call it by no scientific name, I will simply name it the richest of all plants, for it possesses wealth of growth, wealth of development, and wealth of fiber. In ordinary light ground, with a little watering now and then by rain or irrigation, no plant will grow so rapidly, no root will multiply more quickly and produce more stalks; no vegetable fiber is handsomer, richer, or more silky than ramie.

It is a perennial plant, and when once put in the ground it grows for over twenty years without replanting; giving, according to climate, two and three crops a year; it is easy of cultivation, requiring only a soil clean and loose; it is planted in straight rows, three feet apart, in a small up-hill form; the plants must be kept very close, in order to shoot forth straight stalks, without any branches; it grows about like willow, an average of fifteen to twenty switches, from six to eight and ten feet high, covered on the upper part with large green leaves, white underneath. Through its leaves ramie takes its nourishment from the ozone of the air. This developed part of nourishment of the plant, added to the large extensive propensity of the mother-root, from which run horizontally and down a lot of rhizomes and small roots, explain the extraordinary vitality of the plant and its three and four crops a year in some countries.

The Chinese alone have, for a thousand years past, extensively cultivated the ramie plant; before them, the Egyptians were shrouding their dead in magnificent winding sheets of ramie, which to this day are found in the bandages of their mummies. As a textile, therefore, ramie is not precisely a new thing.

How comes the industrial world of this industrial century to be thus backward in introducing practically a plant capable of yielding such important returns and which was made known in Europe by Prof. Roseburgh, director of the Botanical Garden of Calcutta, as long ago as 1803?

The reason is that machinery has been required to do the handwork of the Chinese. No machine can do it at once practically; it requires machinery good for planters, enabling mere separation of the crude bark of the stalks, leaving to industry and chemical agents the task of eliminating the gummy and resinous matters incasing the fiber.

It is then not only a practical machine to peel the bark from the ramie stalks that we want, but also a cheap chemical process to dissolve the foreign matters around the white textile, which has also to be spun on special machinery. Only the perfect knowledge of these connected operations, managed in a business way, will assure in this country the success of the ramie industry.

In a rapid manner I have already explained above the mode of culture of the plant, and I am now preparing to be distributed over all the Southern States a pamphlet giving detailed information on the different phases of the ramie culture.

There is no doubt that Southern planters will go extensively into said culture, when we have here in Philadelphia mills to turn their raw products of ramie into thread finer and stronger than the finest flax thread.

After the cultivation of ramie we have to know how to harvest it, or decorticate it, then to bleach the same and spin it.

It is these three operations that I want to explain here, and on which we experimented last week at Bloomsdale Farm, near Bristol, Pa.

A five acre field was planted with ramie there in May of this year, for experimentation only, because in a general way the ramie culture is not well adapted to this section, the frost here killing the root during the winter; but Philadelphia is an enterprising textile place, and wants to have at hand every element of success. To illustrate what has been done at Bloomsdale, I bring here some green ramie stalks from that place.

A minimum of fifteen of these are growing in a bunch on each plant, and there are 10,000 plants in one acre, say from 150,000 to 200,000 stalks to the acre; an efficient machine had then to be devised to harvest rapidly such a number of stalks.

The decortication or peeling of the fiber from the stalk is done in the following way: (1) By beaters to strip the leaves; (2) a crusher to break the woody part; and (3) other beaters to knock out the wood and get the bark in the way I show you here, which, henceforth, will be the marketable article for planters of ramie. Then the chemical treatment will come in and dissolve the gummy matters in order to get the white textile, which will be spun in Philadelphia. The crude bark is chemically composed as follows:

The cellular portion, embracing cellulose, paracellulose, metacellulose; then vasculose, pectose, cutose, albuminous substances, pectate of lime, some mineral matters in very small quantities.

The cellulose, of which there is about seventy per cent. in Louisiana ramie, is the fiber itself. We have to keep it intact, to get our pure ramie textile, henceforth we have, then, to eliminate the vasculose, pectose, and cutose more or less according to the purposes for which the material is wanted, or for cordage, lace, or damask. If it is for cordage, cutose only must be dissolved; and if for lace or damask, vasculose, pectose, and cutose must be dissolved, to leave the cellulose or fiber entirely pure.

As a guide, it should be noted that boiling diluted hydrochloric acid dissolves pectate of lime, setting free pectic acid, which may be neutralized by an alkali, and it also transforms pectose into pectine, which can be precipitated by alcohol.

Cellulose is dissolved by cupro-ammonium solution; and hydrochloric acid renders paracellulose soluble in cupro-ammonium. Bi-hydrated sulphuric acid dissolves cellulose substances. A boiling solution of potassa dissolves cutose, and under pressure it dissolves vasculose. Diluted nitric acid renders vasculose soluble in alkaline solutions.

The bleaching process consists then in applying the chemical agents in suitable proportions to dissolve slowly the foreign matters we want to get rid of, which are then washed away in running water. The bleaching being done, the fiber is then ready for the mill—but no spinning mill for ramie exists as yet in the United States, and the cotton, wool, flax, and hemp spinners cannot put ramie on their machinery. It requires, from the softener to the spinning frame, provided with numerous small spindles, a series of from eight to ten machines well connected together. When the ramie has passed through these machines it is then turned into strong, fine, glossy thread, from No. 10 to No. 80, which any weaver of the land may use with advantage.

The problem of the practical utilization of ramie is at last on the very road to success in all its branches; this has not been obtained without study and loss of money and time.

To agriculturists, I will say that I have often weighed ramie stalks, grown by myself, in Louisiana. I used to take 150 stalks fully grown, about six feet high; those 150 stalks representing the minimum crop of ten plants. It gave me the following figures:

Plants.	Stalks.	Weight of green stalks with leaves.	Weight of green stalks without leaves.	Crude fiber, wet.	Crude fiber, dry.	Bleached fiber.
		lb.	lb.	lb.	lb.	oz.
10	150	49	29	6	1	7

There are 10,000 plants in one acre, or 1,000 times more than the above table, say 1,000 pounds of crude bark or fiber, dry, and 437 pounds of bleached ramie, per crop, and as there will be two crops if not three yearly, the gross return of an acre of ramie can be easily calculated when I add that crude bark of ramie, dried and baled, is worth from three to five cents a pound, according to quality. I will say, also, that there is in the South not much danger of bad crops of ramie, because it is easy of cultivation, and there is no fear of frost, or of cotton worm on account of the tannin contained in the plant, on which account insects rarely attack ramie plants.

This new product of the Southern States being brought to Philadelphia to be bleached and spun will advance the welfare of this city as has the carpet trade.

Philadelphia is now the greatest carpet-making city in the world. Only about thirty years ago the industry here had its beginning with John Bromley, who worked two looms in a small building. There are now 172 establishments, occupying over 200 large structures, working 7,350 looms and employing 17,800 workmen. They produced last year 71,500,000 yards of carpet, worth nearly $48,000,000. And the price to the consumer has been reduced about one-half.

When ramie shall be woven alone, or with cotton, wool, flax, or silk, as samples here, by every mill in the country, the public at large will find:

That ramie has twice as great strength as flax and hemp, that it washes much better than any other textile, and becomes whiter than hemp and flax.

* A paper read recently before the Franklin Institute and published in the *Journal*.

That ramie, when properly worked, has the luster of silk to such an extent that it is used for many fancy articles, dresses, fine passementeries, portieres, plush, etc.

That ramie is more hygienic than flax, hemp, or cotton, and that its use is recommended in several hospitals for dressing wounds.

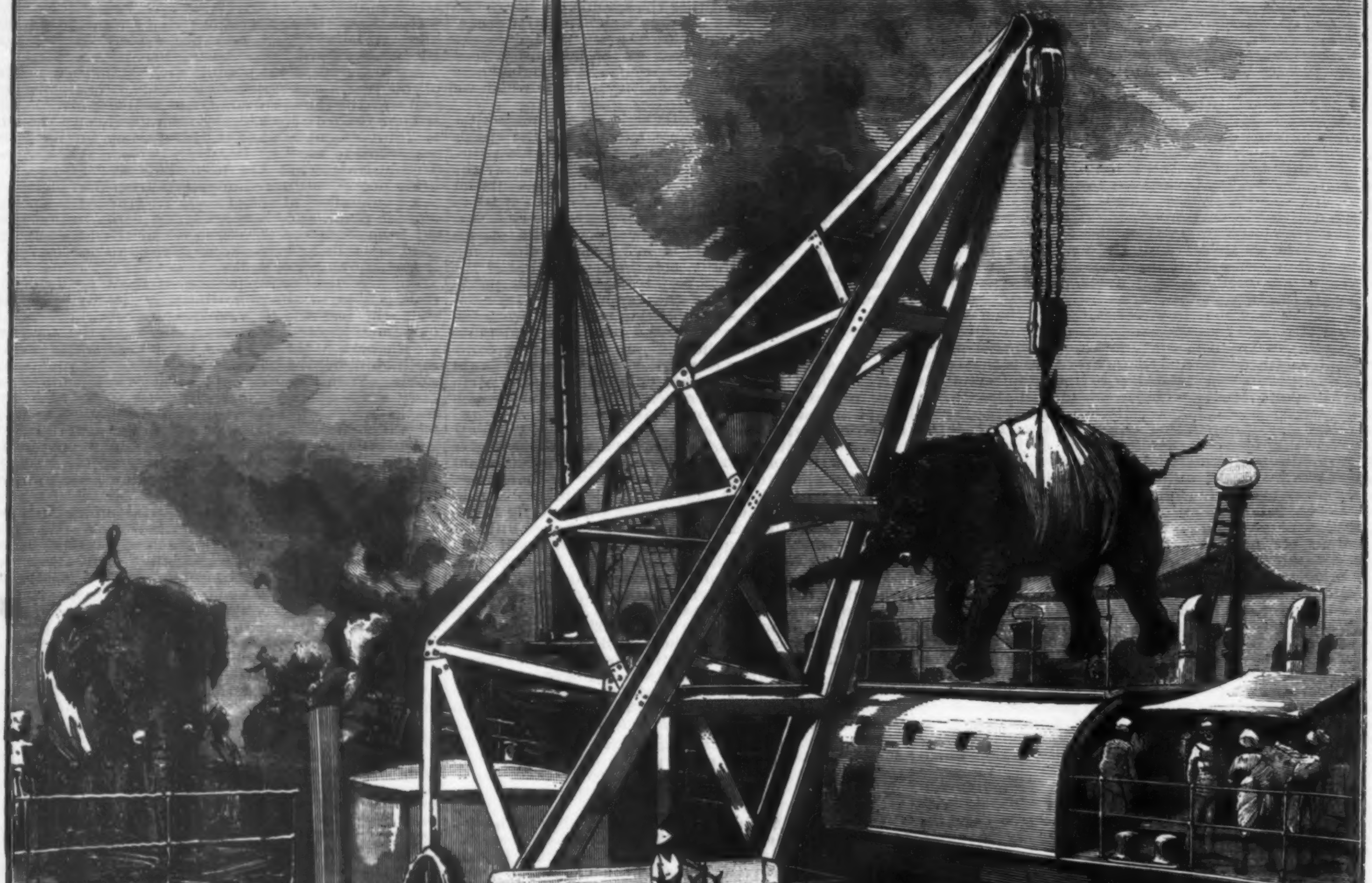
That ramie does not rot in water, and that on this account it is in great demand in the navy for sails, cordage, fishing tackle, and wherever the quality of resistance to the atmosphere and water is needed.

With all the elements of success above explained, and even in the incessant and daily progress which this century makes in all things, commerce, industry, literature, art, science, a new industry of any scope and importance necessitates for rapid development a large center of production and consumption. Philadelphia, I hope, will be this center for the ramie production of the South and the ramie manufacture and consumption for the whole of this great republic.

THE UTILIZATION OF THE ELEPHANT.

The elephant in proportion to his size is probably the least intelligent of any of the animals. But still he is capable of being trained to many useful purposes. In India the elephant takes the place of the horse and the ox for many domestic purposes, being used for drawing, carrying, plowing, etc. In all ages the elephant has been used for military purposes, and until the introduction of modern firearms the animal was an important auxiliary in battle. In the early conflicts between the natives and English in India great numbers of elephants were arrayed against the white men; but instead of assisting the defense, the elephants really became the allies and best helpers of the invaders; for the dreadful sound of the firearms drove the animals mad, and they turned and fled, crushing thousands of the natives beneath their ponderous feet and spreading consternation throughout the ranks of the defenders.

In the British Indian army the use of the elephant for military purposes has for many years proved highly advantageous, especially in transporting guns, ammunition, and stores over rough roads. Ships and cranes are now especially fitted up for elephant transport, and the animals are sent by water from place to place whenever required. Our illustration shows one of these elephant cranes and the mode of transferring these monsters to the shipping. A full-sized elephant in good condition weighs about three tons; but he is lifted and deposited on shipboard almost as quickly as if he were a sack of flour.



SHIPMENT OF MILITARY ELEPHANTS.

One of the heaviest shipments of elephants from this country was that which took place at New York, October 20, when Barnum's show animals were embarked for London. The *Sun* gives the following particulars:

The elephants Babe and Columbia, mother and daughter, that have become famous in Barnum's circus by reason of the strong affection of the mother, Babe, for the daughter, Columbia, and the high temper the mother exhibits when anything occurs to sepa-

rate them, were the two last of the herd of thirteen that were put on board the Anchor line steamer Furnessia recently.

They reached their pens at half past eleven, just five and a half hours after the first one went aboard. Trouble had been anticipated with these two, but they proved the most docile of all. To avoid separating them by hoisting them on board singly, as the others had been, they were led up a specially made gang plank, Columbia first and her mother following.

It took all of Saturday night to get the ponies, sacred cows, and zebras below and the band wagons and chariots on the upper deck.

The valuable buffalo which Mr. Bailey had sent on from Montana died in his box on the pier. Superintendent McLean said that the animal had fretted and worried himself to death.

The yak, a beautiful, silver-haired animal, had a fall at midnight. He was slung in a breeching, and just as everything was ready to lower him down the after hatch he slipped out of the sling and fell at least twenty-five feet, striking full on his left side, breaking two ribs and fracturing several others. He got up and staggered about, and for a time his keepers expected to see him die.

Felix McDonald, the animal trainer and veterinary surgeon who goes with the show, said the animal's chances of recovery are fair, if the weather is good and peritonitis doesn't set in. This and the death of the buffalo were the only accidents which occurred during shipment.

The Messrs. Henderson of the Anchor line and Capt. Martin remained on board all night to see the elephants put on board, but they were disappointed, for it was just six o'clock in the morning when Gyp, the first elephant, was hoisted aboard. She is a careful old body. She sniffed at the big oak cage on the wharf and trumpeted a little, but at a word from Keeper Newman she walked in and allowed herself to be shut up and chained. Then a big derrick hoisted her on board. She was placed facing inboard on the starboard side just abaft the fore rigging. She is twenty-six years old. Nine-year-old Nick was the next elephant put on board. They let him walk out of his cage into the space forward of Gyp. Mandarin, twenty-four years old, came next. He didn't like the cage a bit, but when it was lifted by its three five-inch manila cables, the old fellow showed his presence of mind by getting his sea legs on and bracing himself in sailor fashion. There wasn't any trouble until it came to Don's turn. Don is ten years old, and he appeared to think he knew a thing or two about ships. Up the gangplank he wouldn't go, at least he didn't mean to if he could help it, and the way he smashed boxes and ripped up bales on the pier for a few minutes astonished even his keepers, who finally, however, got steam power at work on him, and fairly dragged him up the gangplank by the neck. When he got half way up, he surrendered. Tip is fourteen years old. He was hoisted aboard next, and then big Fritz, who is twenty-one years old, and generally ugly, but this time he made no trouble. Twenty-eight-year-old Juno followed. Then came Hat, who is 13, and Palla, 23. These two behaved very well, and so did Lena, who is twelve years old, and the little trick elephant Mary, whose age is doubtful. Newman says seven is near it. Babe is twenty-one. Her daughter Columbia is the only elephant ever born in America. Her birthday was March 10, 1880, and her birthplace Philadelphia. Her mother was then owned by the Cooper & Bailey circus. The little elephant was the best attraction that year in any show. The heaviest of them all was Mandarin. He weighs 9,000 pounds. Six heavy oak-framed cages, twelve feet long by eight feet high and about six wide, and weighing about a ton each, were used to hoist the monsters on board and to keep six of them in during the passage. The rest stand in spaces between and at the ends of the cages.

THE JAPANESE PAPER FROG.

THE Minister of Public Instruction, of Japan, sent to the exposition an interesting series of industrial and artistic designs and various samples of joinery, pottery, etc., executed by the male and female children of the infant schools of the country. The specimens exhibited were interesting, and showed much intelligence and taste on the part of the young Japanese designers; but there were also other objects to be seen that were none the less curious. Such were the works of recreation done by the little children of the Azabu private infant school at Tokio. The series of pictures showing colored paper cut out or combined so as to form flowers, butterflies, or marquetry designs were very attractive. It is true that we know in France as well as they do in Japan the pleasing pastime of folding papers, but we must admit that the Japanese have much more ingenious models. The frog that we put before the eyes of our young readers (Fig. 8) is an example of these. It is due to the politeness of the Japanese commissioners that we have been able to trace the figures necessary to form it. It is necessary in the first place to cut a sheet of paper so as to make a perfect square (Fig. 1). This paper is then folded so as to form the diagonals, *a* and *a*, and is then turned in the other direction and folded so as to form the creases at right angles, shown at *bb*. After the folds have been thus well determined it will be easy to form Fig. 2, and then to turn down the ends, *b* and *a*, as shown in Fig. 3. We shall then have a series of eight small panels around the axis, *o a*. After this, it is necessary to take the paper by the point, *b*, and to fold the sheet well so as to make two new regular points as shown in Fig. 4. This operation performed upon the eight faces of the folded paper will give the result shown in Fig. 5. It will be necessary to again fold each face and bend the points, *s*, toward the central axis (Fig. 6), and to take care to form the folds of the points, *a*, as well as possible. Fig. 7 shows what remains to be done to finish the frog. The two upper points, *a*, are raised and bent in order to form the fore legs, and the two other and lower points, *a*, will serve for forming the hind legs.

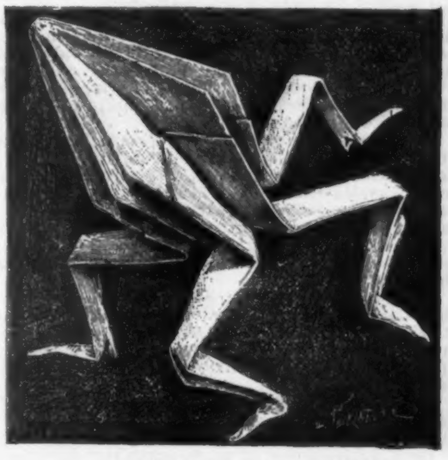
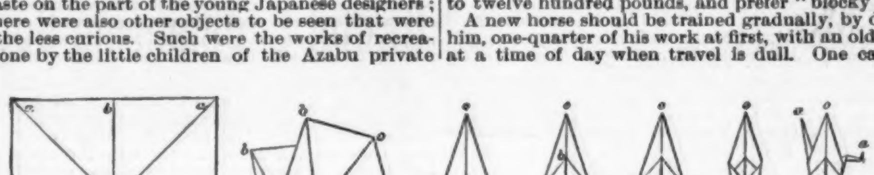


FIG. 8.—JAPANESE PAPER FROG.



FIGS. 1 TO 7.—METHOD OF FORMING THE PAPER FROG.

The left hand side of Fig. 7 shows the unfolded points of paper, and the right hand side gives the aspect of the finished legs of the frog.—*La Nature.*

THE FOOD AND CARE OF HORSES.*

By GEO. G. MULHERN.

THOUGH the place of that noble animal, the horse, is now being usurped by his powerful rivals, electricity and the cable, still he is yet and probably will be for some time the motive power of many a street railroad.

Managers differ greatly as to the subject of this paper, and after an experience of twenty-seven years I find that in this, as in all other business, there is still more to learn.

We have yet to arrive at that state of perfection in the feeding and care of horses when each animal shall receive *just* the right amount of food at exactly the right time, and be cared for and groomed with regard to his own peculiar physical condition. If that state of perfection is ever reached, it will indeed be the horses' millennium.

BUYING THE STOCK.

I have always attended to the choosing and buying of the stock personally; but with all possible care in selection, as to the proper weight, build, etc., for our use, I often find that the animal which seems perfectly fitted for the work "goes all to pieces" in a short time, while the one which I hesitated to purchase as seemingly inferior proves an excellent "railroader."

Places differ so materially, in climate, construction of roads, whether level or hilly, etc., that the kind and size of horse suitable for one part of the country would be entirely unsuitable for another. In this connection I will state that I am inclined to the opinion that horses should be bought near the place where they are to be used. I have found that for our use Ohio stock is best. The experiment of bringing in horses from other States has never been successful with us. Whether the same holds true in other States or is the effect of our peculiar raw climate, I have no knowledge.

We buy horses weighing from ten hundred and fifty to twelve hundred pounds, and prefer "blocky" ones.

A new horse should be trained gradually, by driving him, one-quarter of his work at first, with an old horse, at a time of day when travel is dull. One can soon tell whether he will stand the test or if it is best to sell him as soon as possible. It is a waste of time trying to doctor up a horse whose feet become sore quickly; he will render good service for years on country roads, while on pavements he is useless.

I agree with an able predecessor of mine writing upon this subject, that if it were possible to learn from the owner "the former habits of the animal purchased," it would simplify matters much as to the method of treating him. But as it is a well known fact that in most horse trades the truth is conspicuous by its absence, I fear that reliable information could not be thus obtained.

The comfortless, rattling "bob-tailed" car, drawn by any decrepit old skeleton of a horse that could be bought for a song, and driven by a rusty-looking tramp, is a thing of the past; and the plump, well-groomed and carefully tended street car horse of to-day has become as much a matter of course as the luxurious car which he pulls or the neatly uniformed and polite conductor, so far advanced are we in these modern days.

* A paper recently read before the American Street Railway Association.

FEEDING.

Much of this improvement is doubtless due to the system of feeding now universally conceded to be the best, *i. e.*, mixed ground feed in small quantities and at short intervals. No set rule can be given, as no two horses are alike.

The habits of each horse should be thoroughly learned by the feeder, whose position is a very important one. He should have a certain proportion of horses allotted to his care (not too many), should always feed and tend them himself and become perfectly familiar with the peculiar needs of each.

When a team comes in from their trip, a handful of loose hay should be thrown down to them. Then when their regular time for feeding comes (which should never be just after or just before a trip), they are fed from six to eight quarts of ground oats and corn mixed with cut hay and dampened. They are watered every half trip, oftener in summer. The sponging out of the mouth and nostrils at the end of the trip is very refreshing in hot weather. On our short lines each team does half its work in the morning and half in the afternoon. On our long lines one round trip of fifteen miles constitutes a day's work, with a lay-over of ten minutes at the end of the line, when, on hot days, the sponging referred to above is very beneficial.

We groom our stock twice a day, and I think we will all agree that too much grooming is hardly possible, as the more a horse is groomed the better he feels and therefore gives better satisfaction.

After the horses have stopped eating, the feeder should see that each feed box is thoroughly cleaned out, and he can soon judge of the capacity of the different animals by the amount of food left in the boxes. After he has once learned this there is no necessity for under or over feeding the stock. This cleansing of the boxes is just as essential as the cleanliness of the stable itself, which should be kept thoroughly neat at all times. That it should be well ventilated and lighted we all know. Disinfectants are necessary, especially where there are a large number of horses, when they should be constantly used.

DRIVING.

If the feeder should devote his whole time and attention to the care of his proportion of the stock, so also should the driver. I cannot lay too much stress upon this point. It is a proved fact in my experience that when a team is driven promiscuously, first by one man and then by another, they grow thin and broken down in a comparatively short time; when, if driven constantly by one man, they become accustomed to his voice and touch and keep in good condition.

The man also becomes attached to the team he handles and is much more careful of them, to prevent any unnecessary strain at starting, than if he drives every team in the barn. He is more apt to be watchful and report slight bruises or cuts that, attended to, at once, may prevent permanent injury. I would say, right here, that there should be a positive rule, in every barn, that each driver should have his own stock and should report at the end of each trip the slightest slip or bruise, which, for fear of reproof, they seldom do.

In closing, I feel that I have omitted much that I might wish to say, but have tried to present a few of the more important points of this much debated subject; and though I cannot hope to bring anything new before you, as it has been ably discussed at former conventions, still there is much yet to learn, and in discussing this paper we may receive from your remarks upon it some profitable ideas. Respectfully submitted. GEO. G. MULHERN.

A vote of thanks was tendered to Mr. Mulhern for his able paper.

Mr. William Richardson, of Brooklyn: Mr. President, I think that this paper is of sufficient importance to demand the attention of every man who has the running of a horse railroad. There is not a word in it, I think, that is superfluous, and every word in it conveys useful information and valuable teaching. I feel very thankful to Mr. Mulhern, whom I do not know, for the valuable paper that he has prepared, and which I think should be carefully pondered over by every one of us. What he says about careless driving, the driving by one man, the cleaning out of the feed boxes, the running of teams working on a long distance of fifteen or sixteen miles, so that they may do all their work in one portion of the twenty-four hours and have their entire rest for the other portion, and the manner in which we all find disappointment in the selection of horses. In New York and its vicinity we cannot do as he suggests, get horses raised in the State in sufficient supply and at sufficiently low cost to meet our demands. We have to depend on horses from other States. From his State we get some good horses, but we now get very few, because the home demand takes nearly all of them.

We could get a first class horse from Vermont; but it is very much more costly generally than we can afford to pay. We find that horses from Michigan are good; in fact, from any rolling country State, while the horses from Illinois and Indiana are generally flat footed, and therefore not good for our city pavements. The horses from Minnesota, Iowa, and other rolling or mountainous States are very much better for our use, both on account of the shape of the foot and the greater toughness of the horse. The system in New York is perhaps as nearly perfect for our supply as we can get. We make the best selection of horses that we can, and we get ten days' trial of every horse, to see whether he will answer our purpose, with the perfect right of return to the seller, either with a reason or without one. After ten days we are supposed to have a sufficient trial to enable us to judge whether the horse will suit us; but we find just that same difficulty which Mr. Mulhern alludes to, and that is some of the horses which we think will answer best and have years of service in them would in three months be used up or fit only to be sent on a farm in the country, and others that we expect but little of when we take them—perhaps taking them on an agreement for a longer trial than ten days—will prove the toughest and best horses.

I would like to have heard from him as to what he finds the average life of a horse. We find considerable differences on different portions of our road, where we run several lines. On some it will not be over three and a half to four years. I think the average life in Brooklyn is about a year longer than it is in New York City, judging from my experience in both cities. We will average four or five years, taking one with another. Of course we all know that some will run and keep right along and with but little rest for periods of eight, ten, and even twelve years. It is astonishing, and I think unaccountable, why this difference exists. I do not feel like discussing this, and yet I certainly felt that it was so important in its character that it ought not to be passed without some comment.

For a horse suitable for our use, weighing about eleven hundred pounds, a good, chumpy, well built horse, fifteen and a half to sixteen hands high, active and light on his feet, free from tricks and defects, we are willing to pay one hundred and fifty dollars, if we get ten days' trial. We want first to see if he is a kicker, biter, or balker, or has any other bad traits.

THE COLOR OF HORSES.

Mr. C. D. Wyman, of New York: It may be possible that I can give the experience of the Parisian tramway companies in relation to the matter of color, although I have no doubt that any characteristics of the horse that are revealed by the color would possibly vary as to their utility according to the locality in which they were employed. The Parisian tramcar companies are especially particular in all their statistics relating to their horses, keeping very accurate statistics as to the height, color, and other particulars, to see if there is established thereby any special difference in that respect. They report that the grays are in their experience the longest lived and give them the greatest amount of service, and the blacks the least. In our stable in New York our experience has been somewhat similar. After noticing the French system I made for some years memoranda concerning our own stock, and find that it corresponded somewhat. We found that grays and roans, other things being equal, seemed to be the best for us; while creams and blacks were, as a rule, soonest used up. Particularly we found it true in hot weather that black horses did not seem to have the staying powers that the other horses did. The bays were an average.

WATER FOR HORSES.

There is one other point that I would like to speak of in this connection, and that is in relation to the water that we give our horses. It has been our experience that a microscopical examination of our Croton water revealed at different times different conditions in it of different grades of purity; and it was thought best by the management some four or five months ago to make some experiments in filtering the water. We devised a sort of home-made filter, by placing over the troughs in our stable, of which we have some ten or twelve, a barrel about the size of an ordinary oil barrel, and placing therein charcoal, coarsely ground, with brush and gravel to keep it in position, and we added to that mixture some sulphur. We were led to add this sulphur by reason of the fact that some time ago at Richfield Springs, the sulphur springs, I found that the farmers whenever they had a horse that seemed in poor condition, rather debilitated, brought their horse to drink of the sulphur water. I found that the horses were fond of it; it was necessary to limit the amount of their drink. They would drink until they would almost drown themselves, they were so fond of it. I concluded, from such advice as I could get, that sulphur would be of benefit. We have now been using that filter, with the addition of the sulphur, for about four months. Our cases of colic have decreased seventy-five per cent. In fact, we have hardly had any. Whether it is due to this sulphur and the filtered water I cannot say positively; but that is our opinion. The horses enjoy the water very much. One thing we do know, pretty nearly, as we have examined the water under a microscope, and that is that the horses are getting a pure and good water. I do not know whether the water of other localities might not carry in it as many impurities as ours; nevertheless I give you this suggestion, as it is possible that sometimes the origin of these epidemics that seem to strike a stable and for which we cannot satisfactorily account may lie in the water that we are giving the horses to drink.

Mr. Hall, Illinois: I would like to corroborate Mr. Wyman's statement in regard to the water. I would like to give the convention the benefit of my experience, as a great many will have to continue the use of animal power. I have been managing a road for about sixteen years. For nine years of that time we used the water supply of our city in the barn. My animals got disgusted with it apparently. I went to an expense of a thousand dollars to dig a spring a little distance from the barn to supply them with the water. Before introducing the spring, our medicine bills would run from six to twenty dollars a month for medicine for colic and kindred complaints. Since we have introduced the spring water, I do not remember the passage of a bill by our auditing committee for medicine, except for liniments. Our mules have improved at least fifty per cent. I have not had a case of colic in the barn for two years, and I am here every day when at home.

THE BEST FEED TROUGH.

In this connection I would like to speak in regard to feed troughs. I used primarily the wooden trough, when I used to feed oats and corn whole, and uncut hay. I found that my wooden troughs being square, the corners would get foul and sour. I looked about for a metallic trough, and in investigating the matter wherever I found in use the cast iron trough, I found that it would get rusty and objectionable. The result was I procured some twenty-gallon enamel kettles, and have used them for several years, and never have a sour or foul trough. The stablemen can take a sponge and in ten minutes can clean the troughs for a hundred animals. I never have an animal leave his food in the trough or refuse to eat it.

A LAW has been enacted by Chili, to take effect January 1, 1890, abolishing import duties on machines and tools for use in agriculture, mining, trades, and industries.

FERMENTATIONS.*

By Professor PERCY F. FRANKLAND, Ph.D., B.Sc., GRACE C. FRANKLAND, and J. J. FOX.

THE authors point out how very few of the bacterial fermentations hitherto studied have been performed with ferments of undoubted purity, as well as the insufficiency of the description of the morphological characters of the organisms in question. Such scanty descriptions generally render it impossible for other investigators to know whether they are dealing with the same or with different ferments.

The authors have isolated and fully characterized by the modern methods of cultivation an organism, a small bacillus, which sets up fermentation not only in solutions of glucose, cane sugar, milk sugar, and starch, but also in solutions of mannite, glycerin, and calcium glycerate. The fermentations of mannite and glycerin have alone been so far studied.

In each case the products are essentially the same, viz., principally ethyl alcohol, and acetic acid, together with smaller quantities of formic acid and a trace of succinic acid. The alcohol was separated by distillation and the quantity determined, while the several acids were estimated by conversion into their barium salts in the case of the acetic and formic acids, while the succinic acid was extracted and weighed in the free state.

In the case of the mannite fermentation it was found that the amount of alcohol and acetic acid formed stood in the proportion of two molecules of alcohol to one molecule of acetic acid, while in the glycerin fermentations there were three molecules of alcohol to one of acetic acid.

Of particular interest is the fact that the organism has no fermentative action on dulcite, the isomer of mannite, which thus furnishes a very striking instance of the selective power of micro-organisms between the most closely allied isomeric bodies. The authors were also unable to cause the organism to ferment solutions of either erythrite, ethylene glycol, calcium, lactate, tartrate, citrate, or glycollate.

In view of the characteristic products—ethyl, alcohol, and acetic acid—of the fermentations, the authors propose for the organism the name of *Bacillus ethaceticus*.

* Read before the British Association, Section B, Newcastle meeting.

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